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AEC PILOT-SCALE INCINERATOR CONTROL SYSTEM

Alberta
ENVIRONMENTAL CENTRE

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AEC PILOT-SCALE INCINERATOR CONTROL SYSTEM

by
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Alberta Environmental Centre

November 24, 1994

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Implementation of the control system was performed by members of the Instrumentation and Controls Section. David Mewis[1] programmed the PLC (Programmable Logic Controller) ladder diagrams and configured the controllers and the calculation blocks. Dr. Slawomir Apuniewich, a contract engineer, made further operational improvements and adaptations to accommodate added equipment. He also ported the control system to a 386 based ONSPEC™ and was responsible for modifications of displays and communication setups. Ted Singh[1] configured the ONSPEC™ database and built the initial display screens. D. Mewis initiated wiring documentation but most of the work was done by Fred Becker who also produced some of the drawings for this publication. Kurt Klingbeil installed networking hardware and software; as well, he wrote the communication driver for the TI (Texas Instrument) data acquisition system.

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[1] No longer with the Alberta Environmental Centre.

1 INTRODUCTION

Since the conception and implementation of the control system for the pilot-scale research incinerator at the Alberta Environmental Centre (AEC), many people involved in the initial effort have left the Centre. Many subsequent additions and changes to the system were performed by contract or other temporary staff. As a result, details of the design on the operational level is fragmented. This report describes the incinerator control system and creates a basis for further work to improve the quality and reliability of controls.

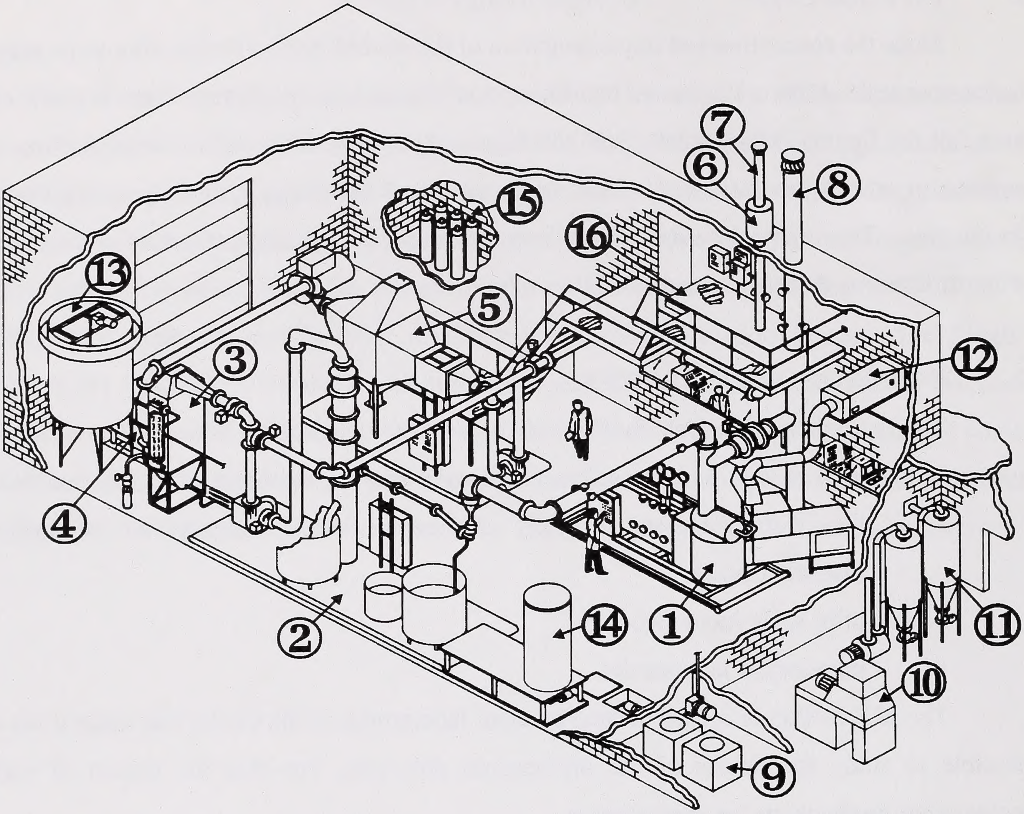
2 INCINERATOR DESCRIPTION

The Incinerator Research Building (IRB) at AEC is a facility hosting a comprehensive system to study all aspects of incineration processes. Main components of this system are:

- bench scale incinerator, fully instrumented with complete set of analytical instrumentation,
- pilot scale incinerator,
- preparation laboratories.

The IRB facility is complemented by other laboratories at the Centre that make it not only possible to study the details of the incineration processes, but also the impact of various incineration products on the environment.

The major process components of the Pilot Scale Incinerator are: the Incinerator comprising of four combustion chambers, followed by a Venturi and Packed Column Scrubbers, Carbon Adsorber, and Exhaust Reheater unit. Figure 1 provides a layout of the Process and Auxiliary Equipment for the pilot-scale incinerator system. These process units are controlled by the AEC Pilot-Scale Incinerator Control System. The main functions of the Incinerator Control System (ICS) is to ensure the safe operation of the process devices; maintain temperatures, oxygen levels and pressures in combustion chambers and other units; and protect devices and operating personnel through alarming and safety interlocks. Regulation of various process parameters is performed by 17 control loops of Programmable Logic Controllers (PLCs). Operator Interface to the control function is provided by the ONSPEC^{TM} package. It allows recording of process information, viewing of trends and alarms, and operating devices using computer screens. The purpose of this report is to provide the reader with more detailed information on the Incineration Control System.



LEGEND

1.	Incinerator	9.	Tote Tanks
2.	Wet Scrubber	10.	Hammermill
3.	Heat Exchanger	11.	Ash Removal System
4.	Electric Reheater	12.	Fugitive Fume Control
5.	Adsorber System	13.	Clarifier
6.	Stack Reheater	14.	Storage Tank
7.	Treated Gas Stack	15.	Gas Cylinders
8.	Emergency Stack	16.	Sampling Platform

Figure 1 Layout of the Process and Auxiliary Equipment

3 APPROACH

The design philosophy of the system was based on meeting the following functional requirements:

- flexible data presentation, archiving and retrieval;
- proportional and discrete logic controls; and
- safety interlocks and alarming.

Hardware selection criteria included:

- structural and functional flexibility; and
- cost effectiveness.

To achieve these objectives, a design based on the combination of PLC controls and IBM-PC based operator interface software was chosen. Commercially available PLCs provide the required structural and functional flexibility through programmability using advanced software ladder diagram programs. These programs also allow checking and debugging through monitoring and simulating of different system conditions. Built-in documentation facilities make maintenance and modification easy to perform. PLC hardware and firmware offer a very high level of operational reliability; at the same time, they are very cost effective. The Westinghouse PLC model, PC-900, meets both functional and cost requirements.

IBM-PC based operator interface software complements the relay logic. It achieves the required level of sophistication, functionality and cost effectiveness. The IBM-PC compatible hardware platform that runs the software offers high performance at low cost. The DOS operating environment is simple and user friendly. There is a wide range of software products available for data post-processing, graphing, etc. Staff are familiar with DOS along with many general purpose application programs such as Lotus, and D Base. We have selected ONSPEC™ control software from Heuristics as a package best suited for our application.

ONSPEC™ runs under the Digital Research Concurrent DOS operating system. Concurrent DOS fills the multitasking deficiency gap of MS DOS and allows operators to run many custom programs concurrently with the ONSPEC™ control package. These programs may be required to aid the operator in data analysis. One such package is the "Super Trend" trending software and another is the on-line "SuperCalc" spread sheet, both from Heruistics. ONSPEC™ provides the designer with ready-made controller face-plates and many graphic symbols to build control displays. The advanced controls module makes more advanced algorithms, such as feedforward, readily available to an application (i.e. without the need to write programs). Configuration of controls and displays is performed by filling in blanks on screen templates. To provide flexible access to data and displays and control manipulation by both the operator and scientists involved in the incinerator run, three AT compatible, 80386 microprocessor based computers are linked in a network configuration, which allows sharing of both files and the ONSPEC^{TM} on-line control data base.

For data logging of less critical and slowly varying signals, an available analog device, a MACSYM$^{(TM)}$ laboratory data logger was used in conjunction with the Scanivalve - an electro-mechanical multiplexer.

Scanivalve offers a cost effective solution to pneumatic signals. The cost of one channel of a Validyne pneumatic transducer is approximately $1000.00, while for around $2000.00, a Scanivalve unit provides 12 pneumatic channels per rotor. Additional rotors carrying 12 channels cost $600 each. In addition, the unit supports multiplexing of low level signals from thermocouples. Non-critical analog signals are mostly wired directly to the Macsym data logger. Signals required for controls are wired directly to the PLC cards. The Macsym based data acquisitions system was operational for a few years until it was damaged by a water leak. A Texas Instruments PLC model 545 has replaced it. The TI system provided the capabilities of the original Macsym data acquisition system and also offered expansion capacity needed for future control applications. A block diagram of the control hardware is shown in Figure 2.

4 CONTROL LOOPS

Control loops are implemented in the Westinghouse PLC. The following types of control loops are utilized:

- Flow;
- Air/fuel ratio;
- Temperature;
- Pressure and differential pressure; and
- pH.

The typical control loop uses the general PID algorithm available on the PLC. Algorithm parameters are entered into the PLC using specially designed screens from ONSPEC^{TM}.

Depending on loop requirements, sometimes only proportional (P) or proportional and integral (PI) sections are used.

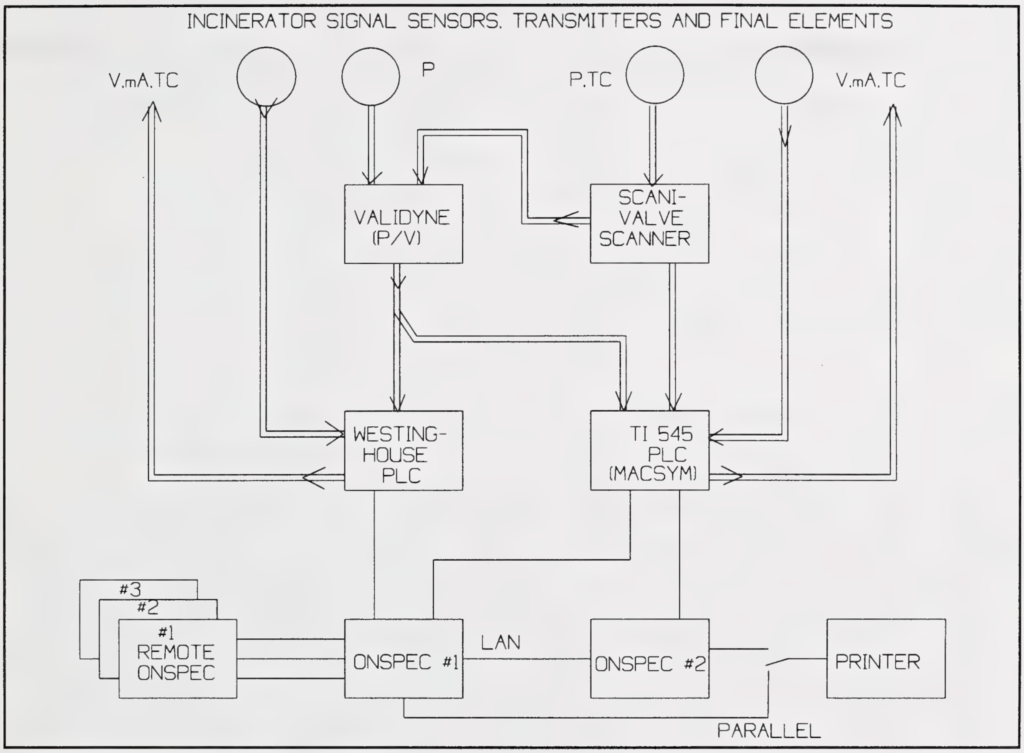


Figure 2 System Block Diagram

4.1 Flow Controls

A typical flow control loop is shown in Figure 3.

Flow rate is measured by the differential pressure at the orifice or venturi sensing element and is controlled by an electro-mechanical positioning actuator (Honeywell Modutrol) moving a valve. The PLC processes input signals and PI algorithms; actions are controlled by varying the strength of the output signals. Actuators inherited from past designs exhibited substantial positional hysteresis. Instrumentation and Control Section staff modified the actuators to decrease this hysteresis from 4.4% to approximately 2%. Further decrease in hysteresis width is not possible because of the design of the actuator feedback potentiometer. Its resistive element is

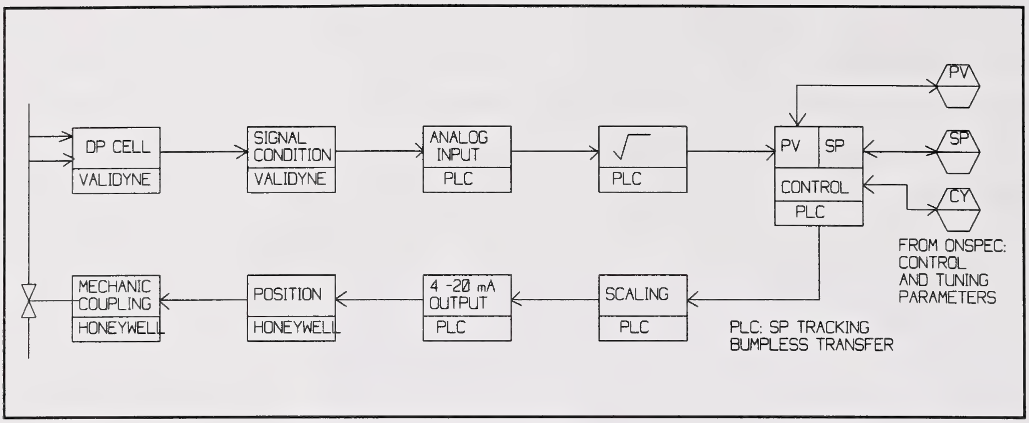


Figure 3 Flow Control Loop

too coarsely wound and further reduction of hysteresis results in a jumpy feedback signal and quick deterioration of the actuators and valves.

However, for the liquid flow control loop, this type of actuator is not suitable and was replaced by a pneumatic control valve. A mass flow-meter is used to measure liquid flow rate.

The mechanical linkages of the air valves in the air flow control loops are arranged so that when completely closed some air passage still occurs; this provides air for the pilot flame and prevents accidental starvation of the flame, particularly during initial ignition, re-ignition or during transient action of the controller. In addition, some flame control loops have been designed to prevent complete closure of the gas valves during control action. This avoids triggering of the "flame failed" signal, and obviates the need for special circuits to differentiate between "flame off" due to abnormal, dangerous conditions and "safe flame shut-down" conditions resulting from the controller action.

4.2 Ignition Control and Flame Monitoring

The multi-fuel main burner incinerates gas as well as liquid waste using gas or liquid as a fuel. During start-up, a pilot flame is ignited first. The pilot flame is monitored by a Fire Eye$^{(TM)}$ safety circuit. It is wired to activate the ignition coil when the flame goes out. If the pilot is not re-ignited within five seconds, the Fire Eye$^{(TM)}$ causes the main fuel valves to shutdown and triggers the "Pilot failed" relay. This relay, once triggered, cannot be reset for a few minutes. The reset has to be manually pressed at the Fire Eye panel.

The main burner has a double circuit for flame monitoring. Under some conditions the flame may separate from the nozzle, creating the possibility of an explosion. The second Fire Eye(TM) monitors for this condition. When this condition is detected, the safety circuit attempts to re-ignite; if unsuccessful within five seconds, the safety circuit will shut down the main fuel valves.

There is a special switching logic implemented in the PLC that can prevent the "Pilot failed" relay from triggering. This special switching circuit lets the operator re-ignite the pilot remotely from a computer console. This circuit is described in more detail later in this report. Burners on chambers #2 and #3 do not have pilot flames.

4.3 Air/Fuel Ratio Control

At start-up, the air/fuel (A/F) ratio is set to a default value. Oxygen analyzers are used to measure oxygen content and control the A/F ratio. They require proper operating temperatures to function. During warm-up, the analyzer control loops are disabled so the A/F ratio can be adjusted manually within preset safety (high, low) limits. Once the initial warm-up is complete, the oxygen analyzer loop is cascaded to control A/F ratio based on the readout of the oxygen analyzer. Figure 4 depicts the ratio control section of the incinerator control system. In addition, an anti-smoke arrangement using process lag prevents oxygen deficiency (and generation of smoke) during load variation. The anti-smoke circuit is described in the next section.

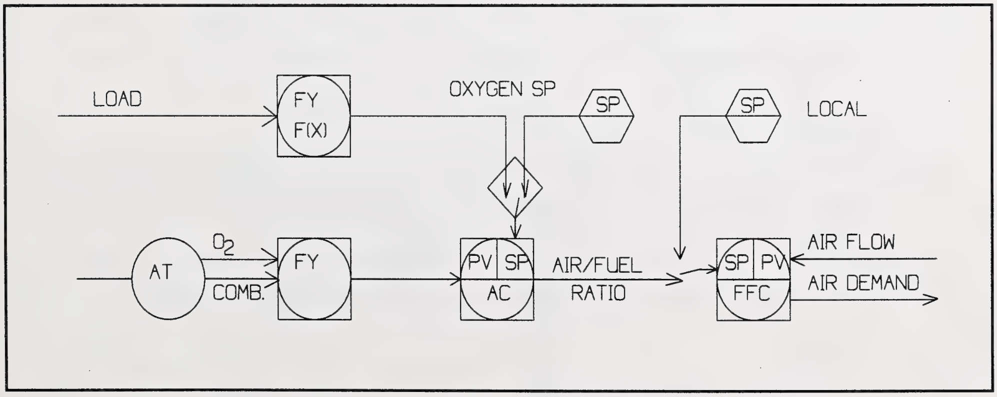


Figure 4 Air/Fuel Ratio Control

4.4 Temperature Control with Anti-Smoke Control Circuit

The temperature control circuit use a cross-limiting (lead-lag) anti-smoking arrangement. The structure of this circuit is shown in Figure 5.

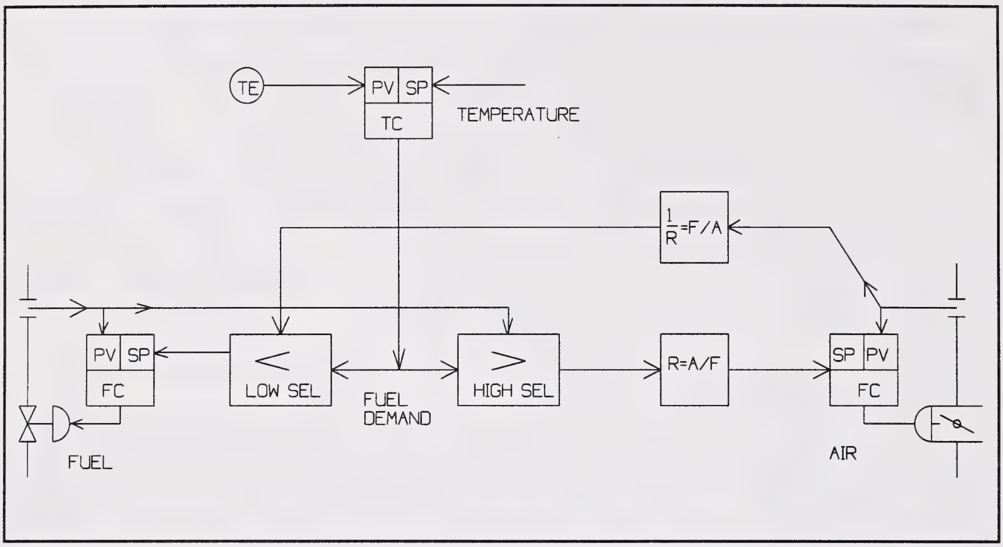


Figure 5 Typical Temperature Control Loop

The PI controller compares setpoint temperature with the actual measured temperature and produces the "fuel demand" output signal. To produce a flow setpoint value for fuel and air controllers, this signal is passed through low and high selectors. The low selector compares actual fuel flow with the demand signal and selects the lower value of the two, thus assuring that the A/F ratio does not fall below the set value during transition from increased fuel demand. Alternatively, the high selector compares actual air flow rate with the demand signal and selects the larger value, assuring that the A/F ratio will not decrease during transition from decreased fuel demand. Since actual flows lag behind setpoint demands, this circuit increases the A/F ratio either when there is an increase or a decrease in the fuel demand, thus preventing smoke creation during the transition period. The properties of the circuit are summarized below:

On increased demand:

- following demand, air increases first
- fuel follows air, lagging behind demand.

On decreased demand:

- following demand, fuel decreases first
- air follows fuel, lagging behind demand.

In the steady-state condition:

- the air/fuel ratio is in balance
- air follows the fuel flow in the ratio specified by the oxygen analyzer.

In our installation some of the selectors are slightly biased to cut off part of the noise spikes present on control signals. These transition spikes are generated at the steady state condition because of the substantial hysteresis of the Honeywell actuators. Biasing improves the quality of the control signals while maintaining the benefits of the anti-smoking circuit.

4.5 Preferential Waste Fuel Firing

The main burner can burn gas and liquid at the same time. Usually the waste being incinerated is liquid. The preferential firing circuit helps to use caloric value of the liquid waste by making liquid more preferable fuel than gas. This is important when working with liquids which have high combustion energy comparable to that of natural gas. Figure 6 illustrates the structure of this circuit.

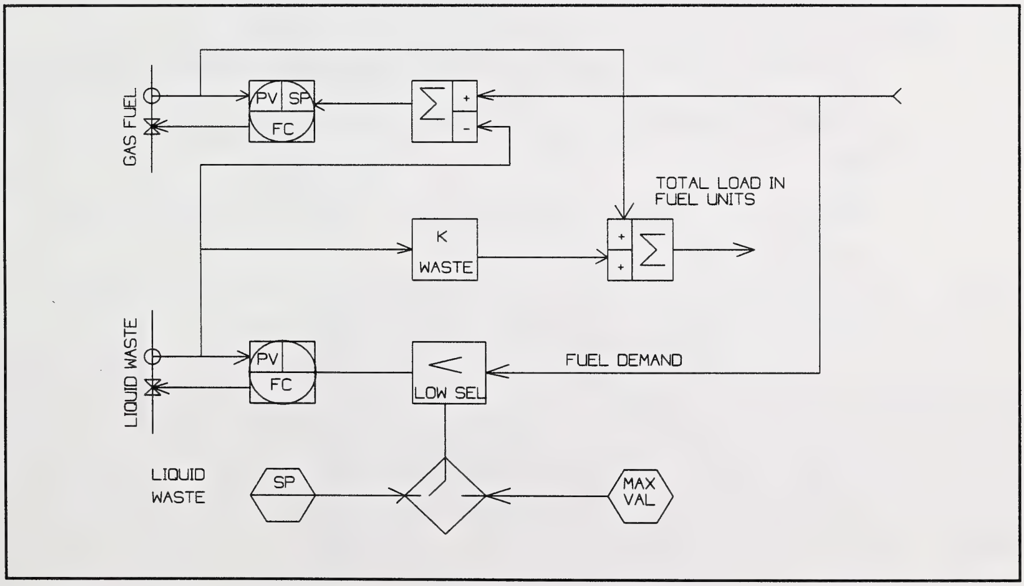


Figure 6 Preferential Waste Fuel Firing Circuit

This circuit lets an operator set the desired value of the liquid waste flow rate. This set value becomes the high limit for the waste flow rate. The low selector compares demand for the fuel with the set value and selects the smaller value. When the caloric value of the liquid is not sufficient to maintain the required temperature, gas, which serves as the auxiliary fuel, is fired. When the caloric value of the liquid is high and the waste flow rate setpoint is set too high, an excessive rise in the chamber temperature occurs. Consequently, the low selector selects the fuel demand signal with the lower value put out by the temperature controller and decreases the flow rate of the waste that is required to maintain the temperature at setpoint level. The caloric value of liquid is subtracted from the total demand for fuel and this difference is passed to the gas flow controller. When the caloric value of liquid is negative the demand for gas increases with an increase of liquid flow rate. The coefficient representing the caloric value of waste compared to gas is entered in the PLC using an ONSPEC™ screen. This coefficient can be very approximate, since the controller can compensate for discrepancy through a control action.

4.6 Controlling Incineration of Solids

Chamber #2 ('solids chamber') burns solid waste. In this mode of operation, the guillotine door closes and separates chamber 1 from chamber 2. It is more difficult controlling the incineration of solids than liquids. Three elements achieve control:

1. A gas burner, with its combustion air supply, initially heats the chamber and maintains temperature at a preset value set above the ignition level for solids waste.
2. "Under-fire air" controls the combustion rate by controlling the amount of available oxygen.
3. Steam quenches the fire when it is out of control.

Figure 7 illustrates the control structure for the solid waste combustion chamber. During normal operation chamber #2 is expected to burn solids with an oxygen deficiency. The flow rate of the "under-fire air" controls the amount of available air in the chamber. In this operation, adding more air increases combustion rate, while removing air decreases combustion rate. This is based on the assumption that combustion rate is proportional to the amount of available oxygen. An analyzer whose probe is placed in the entrance to the third chamber monitors the level of oxygen, or combustibles. Temperature variation has an important effect on the rate of combustion, strongly influencing the decomposition rate and sometimes even changing how decomposition is performed and producing different byproducts of incomplete combustion. In bulk, stationary solids, there are wide local temperature gradients. They cannot be controlled because heat generation and exchange is governed by local physical-chemical processes. There is no access parameter for combustion control except the global, external parameters like air flow rate and chamber temperature. Thus, combustion can become uncontrollable.

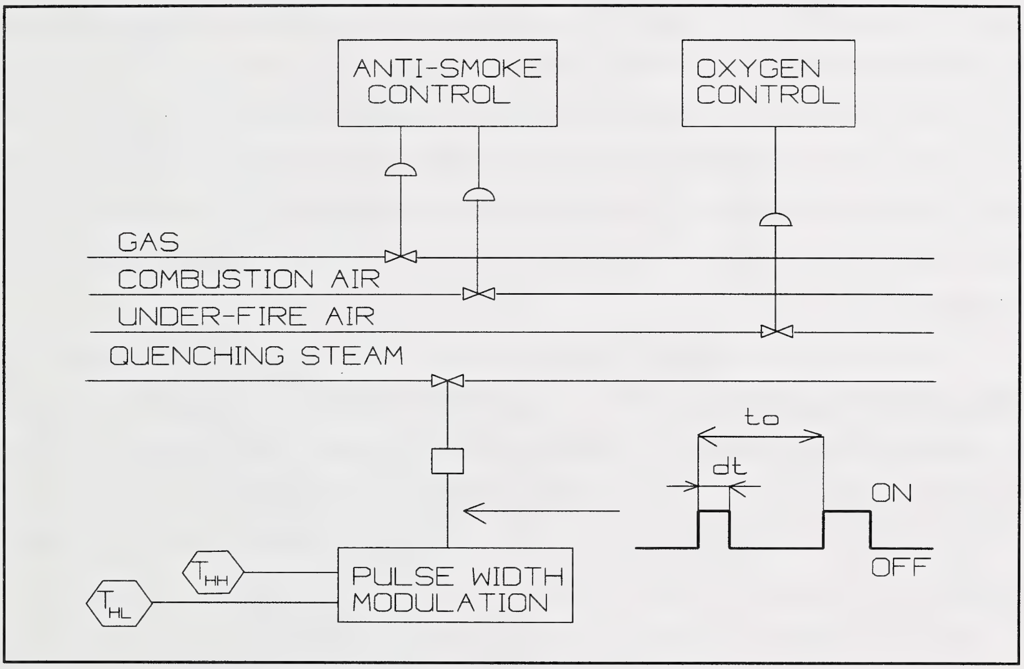


Figure 7 Solid Waste Control

When the temperature exceeds the setpoint by a preset value, the amount of "under-fire air" available for combustion is regulated for further control and air is replaced with steam. This transition is governed by safety limits. Two safety limits are involved in monitoring "run-out conditions", HL-high limit and HH-high, high limit. When the chamber temperature exceeds the HL safety limits, steam is injected into the chamber. A P-controller using pulse width modulation controls the injection rate. The proportional rate is set such that at the HH temperature level, duty cycle reaches 100%. The formula used is

$$\Delta t = \frac{T - T_{HL}}{T_{HH} - T_{H}} \cdot t_{o} \text{ ; } \textit{if current temperature } T \geq T_{HL} \textit{ otherwise } \Delta t = 0$$

The above control strategy has been tested. It did not provide sufficient control during the transitional period, which occurs after placing a new load in the chamber. Loading of solids cools the chamber. Upon closure of the loading doors, the control system activates the burner to keep the temperature at the setpoint level. After some delay, solid waste is ignited, resulting in rapid combustion and an overshoot in the temperature. Because of the speed of the ignition process and air leaks to the chamber, it is difficult to keep the oxygen deficiency at a constant level. A delay in the temperature controller activation is a partially successful solution to the problem. A controller, using the combustion model as the reference to derive the controller action, would be more appropriate. Further examination of this area should achieve better control of the process.

The effect of an air flow on combustion is two-fold: on one hand, it provides more oxygen and thus increases the combustion rate; and on the other hand, it cools the waste material, thus decreasing the combustion rate. At some flow rates, these two competing influences balance, resulting in combustion curves with maximums as illustrated in Figure 8.

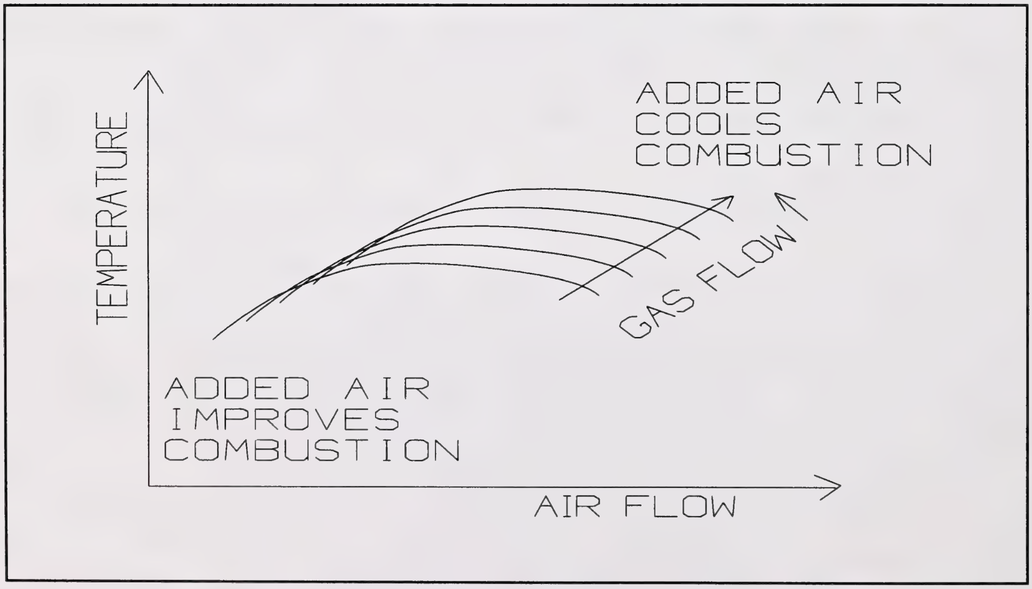


Figure 8 Chamber Temperature as Function of Air Flow

There is an inherent difficulty in the combustion process control, achieved by regulating air available for combustion, evident from the shape of the curve in Figure 8. As the operating point moves from the left to the right of the maximum, the differential gain of the loop changes not only value but also sign. Negative feedback becomes positive, making the loop unstable. This situation can produce another kind of run-off condition - cooling-off caused by excessive air flow. This may happen temporarily because of the slow response of the oxygen analyzer loop. Upon detection of excess air, the oxygen control loop reduces air flow rate to the left of the maximum. In addition, note that the actual "work curve" of temperature vs air flow rate is fundamentally modified by the control action of the temperature controller changing the burn rate of the gas. The temperature drop is offset by an increase in gas flow.

Excessive air flow rates cause particles of ash and incompletely burned solid matter to rise and be carried out of the chamber, which is not a desired result.

4.7 Pressure Control

Before flue gas is exhausted to the air, it is scrubbed in venturi and packed column scrubbers, cleaned in a carbon adsorber and then reheated. To overcome the flow obstructions of these devices and maintain a negative pressure in the incinerator chambers, two fans suck in the air and push it through ducts. The pressure control loops maintain a proper level of pressures in the incineration chambers, ducts and carbon adsorber. Excess vacuum may cause ducts to collapse; under positive pressure incineration products escape to the inside of the incinerator building. The control loops are shown in Figure 9.

There are three independent loops. The first loop controls differential pressure in the incinerator chambers, the second maintains the proper pressure level in ducts and the third controls pressure drop across the venturi in the wet scrubber. These loops are strongly coupled. A valve regulates the pressure drop across the venturi which affects the scrubbing performance. The PID loop maintains this pressure drop at a constant set-point level. There is a strong interaction between this loop and the first fan control loop; more design effort is required to further improve control quality. When required, the wet scrubber loop can be set to manual mode. A more sophisticated control scheme may be considered in the future to improve control quality. Currently the two fan loops' interaction is minimized by a time scale separation; the first fan control loop operates quickly, the second slowly. This arrangement matches the natural dynamics of the subsystems.

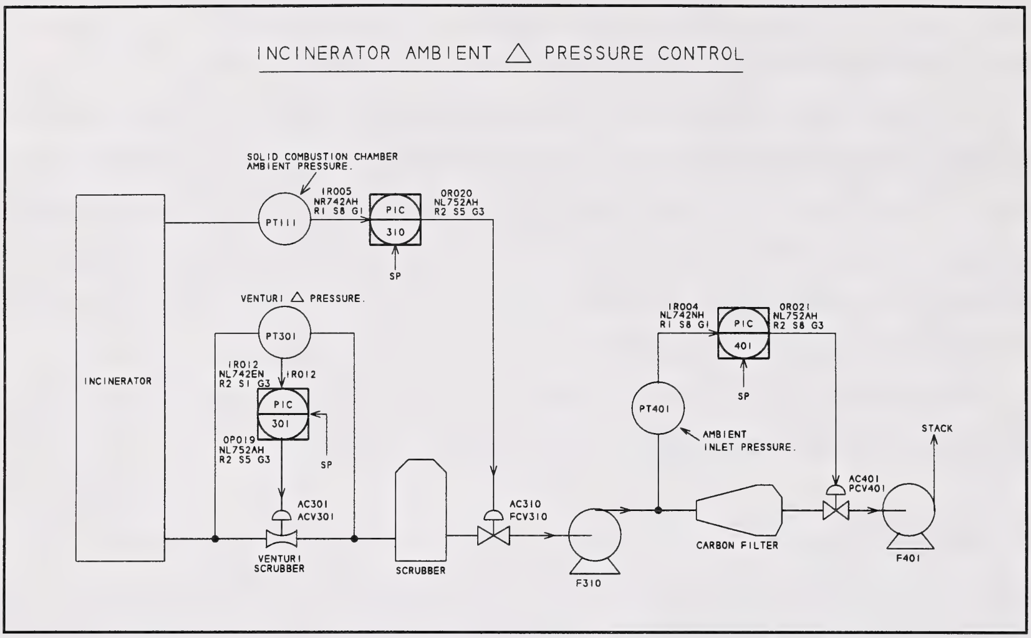


Figure 9 Pressure Control in Incinerator Chambers and Ducts

4.8 pH Control

The two collector tanks for the venturi and packed column scrubbers require that pH be maintained within operating limits. The requirements are not very strict; two stand-alone PID control loops achieve this task. These controllers are not connected to the computer and their set points are manually adjusted at the instrumentation cabinet. pH values are available as analog inputs to the computer. The lack of remote setpoint control of pH controllers results from the fact that pH values need not be changed often and the extra cost is not justified. Appendix "F" shows control arrangements in more detail.

5 SAFETY INTERLOCKS

Numerous interlocks improve operational safety and also protect staff and equipment in the event of equipment malfunction or human error. The basic interlocks are at the device level and they are used to ensure the proper operation of devices. For example, consider Burner 1 (Liquid Chamber): the following conditions must be satisfied to ignite this burner:

- power on, air supply available, pilot flame on, guillotine door up, temperature in the chamber below high safety limit, gas pressure above low limit, etc.

These single device level interlocks then become the building blocks of a more complex, total system interlock logic. This logic ensures that the plant equipment is brought on line in the proper sequence. For example, the by pass valve cannot be activated if both fans are not working, duct pressures are not within the right range, the wet scrubber is not in operation, and so on. Bash Pandompatam specified the interlocking system, shown in Figure 10a.

Typically, the operation sequence of the Pilot-Scale Incinerator involves plant start-up, normal operation and shut-down. Start-up and shut-down are transitory in nature and during these events the process parameters change widely until they reach the target values, while the goal of the normal operation is to keep the process parameters as steady as possible. Most of the interlocks are static by nature and are valid during all phases of the plant operation. In general, there are some interlocking requirements that are valid only during the transitory phases or only during normal operation. Switching logic has to handle all cases. To complicate matters further, many process units have been equipped with built-in electromechanical interlocks. We decided to utilize these electromechanical controls in the total plant control system rather than to replace them with an "all in the PLC" implementation. Such solution has some advantages:

- Equipment can be operated from local panels.
- Individual units can be operated without the PLC, which was important during plant construction and remains so during maintenance.
- Cost of the PLC hardware would have approximately doubled.
- Extra work would have been necessary to dismantle panels, rewire sensors to the PLC and test the modified logic.

Figure 11 illustrates a typical technique for interfacing relay logic with the control panels of the PLC computer. One contact isolates the local switch and the second controls the PLC ON/OFF switch. The hand switch position is not confirmed but a special Local/PLC selector switch, readable by the PLC, enables/disables activation of devices for the local panels. This arrangement provides maintenance convenience; the local switches are not used during normal operations. Figure 12 shows a portion of the panel interfacing.

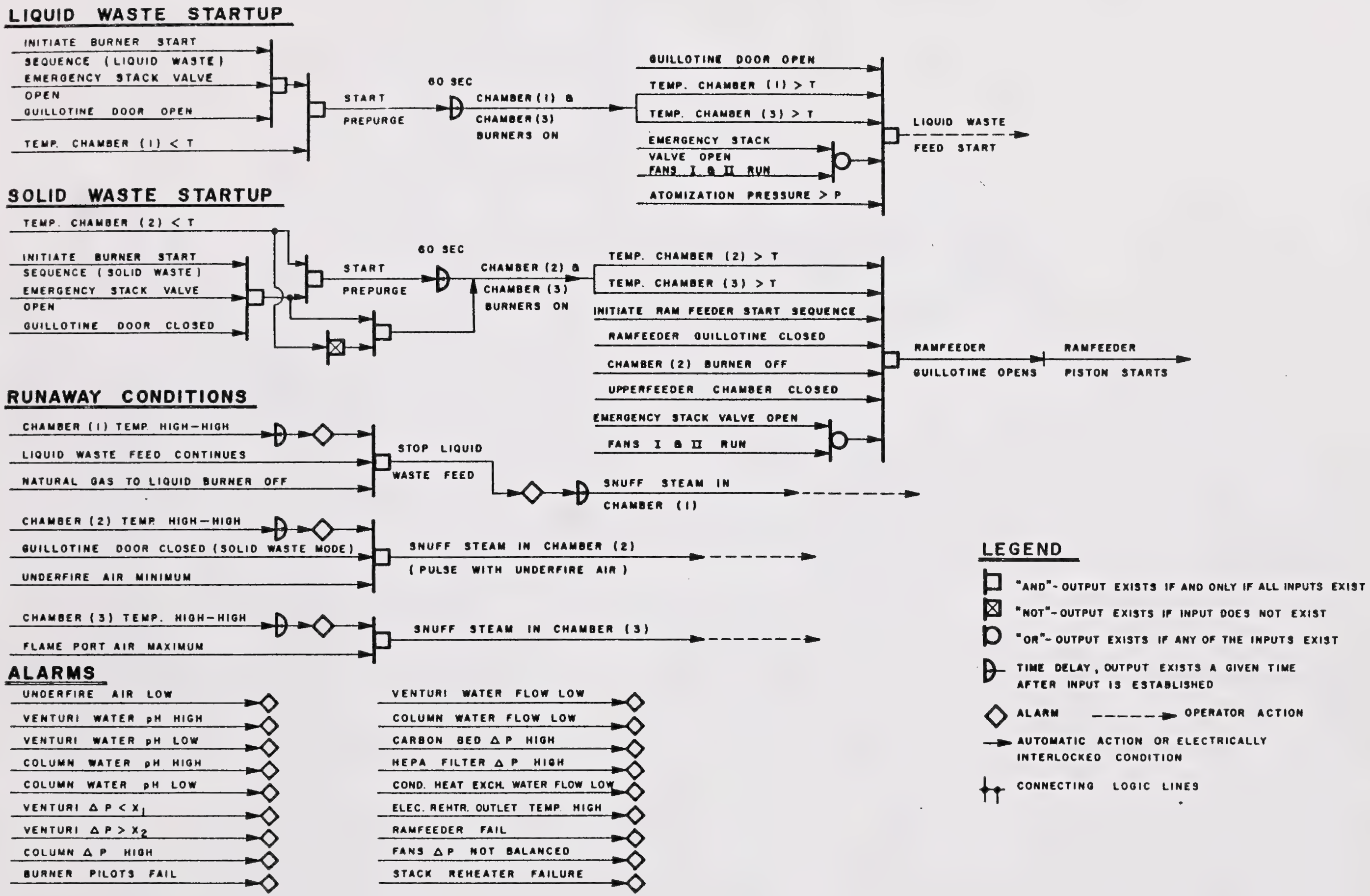


Figure 10a Safety Interlocks for Incinerator Control

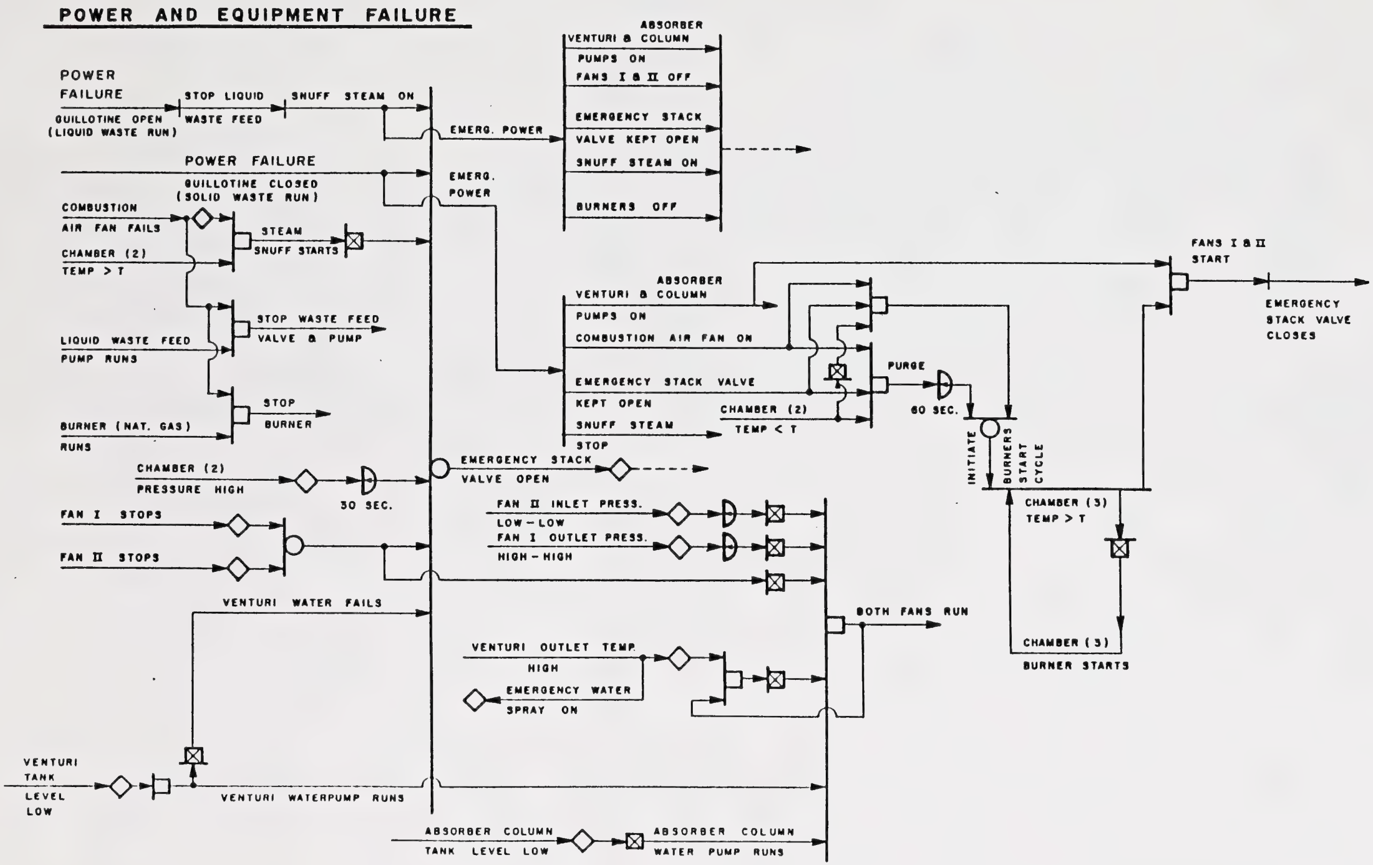

POWER AND EQUIPMENT FAILURE
POWER FAILURE
GUILLOTINE OPEN (LIQUID WASTE RUN)
STOP LIQUID WASTE FEED
SNUFF STEAM ON
EMERG. POWER
ABSORBER VENTURI & COLUMN PUMPS ON
FANS I & II OFF
EMERGENCY STACK VALVE KEPT OPEN
SNUFF STEAM ON
BURNERS OFF
POWER FAILURE
GUILLOTINE CLOSED (SOLID WASTE RUN)
EMERG. POWER
COMBUSTION AIR FAN FAILS
CHAMBER (2) TEMP > T
STEAM SNUFF STARTS
LIQUID WASTE FEED PUMP RUNS
STOP WASTE FEED VALVE & PUMP
BURNER (NAT. GAS) RUNS
STOP BURNER
CHAMBER (2) PRESSURE HIGH
30 SEC.
EMERGENCY STACK VALVE OPEN
FAN I STOPS
FAN II STOPS
VENTURI WATER FAILS
ABSORBER VENTURI & COLUMN PUMPS ON
COMBUSTION AIR FAN ON
EMERGENCY STACK VALVE KEPT OPEN
SNUFF STEAM STOP
CHAMBER (2) TEMP < T
PURGE
60 SEC.
INITIATE
BURNERS START CYCLE
FANS I & II START
EMERGENCY STACK VALVE CLOSES
CHAMBER (3) TEMP > T
CHAMBER (3) BURNER STARTS
FAN II INLET PRESS. LOW-LOW
FAN I OUTLET PRESS. HIGH-HIGH
BOTH FANS RUN
VENTURI OUTLET TEMP. HIGH
EMERGENCY WATER SPRAY ON
VENTURI TANK LEVEL LOW
VENTURI WATERPUMP RUNS
ABSORBER COLUMN TANK LEVEL LOW
ABSORBER COLUMN WATER PUMP RUNS

Figure 10b Safety Interlocks for Incinerator Control

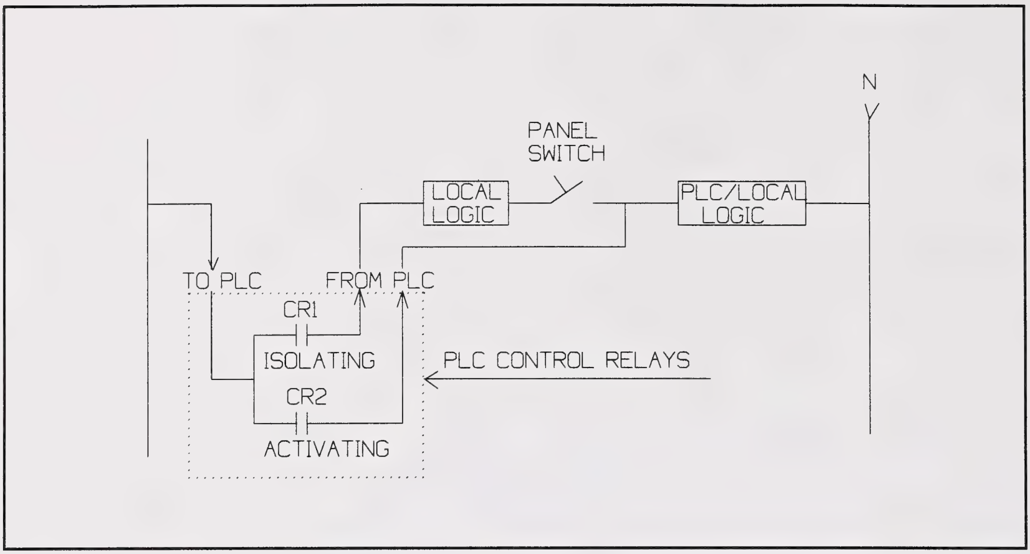


Figure 11 Interface to Panel Switches and Sensors

6 OPERATOR INTERFACE

6.1 Introduction

The incinerator control system was designed to separate and decouple, as much as possible, the control functions from the operator interface functions. Due to the limited reliability of the PC computers, both in hardware and particularly in operating systems and application software, we decided not to put any control functions on the PC computers. This requirement could be eased up by allowing noncritical, supervisory type control functions to be located on the PCs. Brief hang-ups on the computer would still allow the plant to run safely and not necessitate the plant being shut down.

In addition to providing displays of the plants' operation, the process computer should have the ability to run various auxiliary programs which augment or rearrange information required by scientists involved in experiments. A Concurrent DOS based system allowed us to achieve these goals without resorting to solutions that provide uniquely customized, real time DOS extensions that are not portable between vendors. Currently, more options are available, particularly control interfaces based on OS/2 operating systems, that more readily achieve these goals.

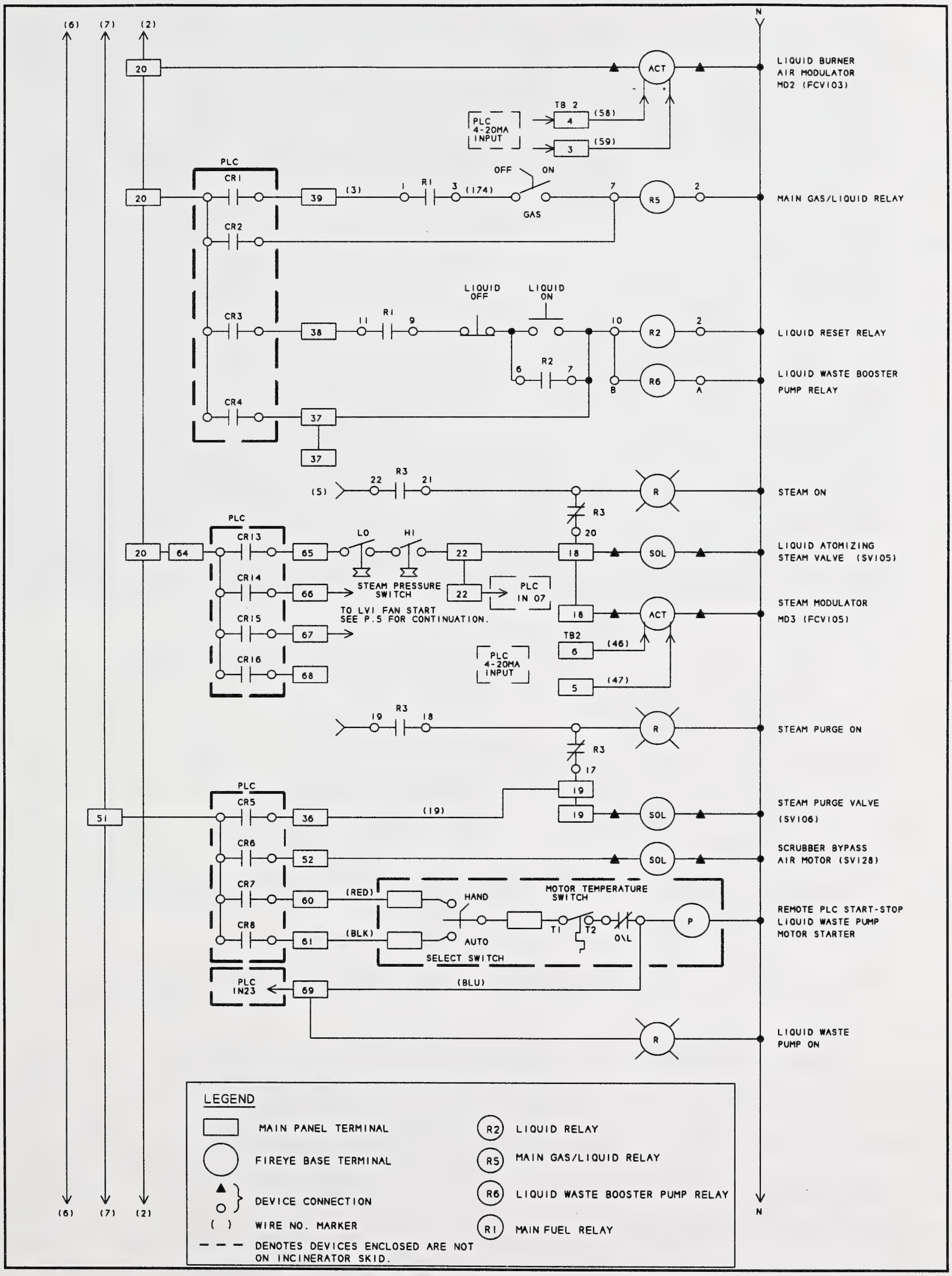


Figure 12 PLC - Panel Interface Logic

The ladder diagrams, operator interfaces, and plant construction were implemented concurrently. Thus, implementation proceeded in a bottom-up fashion, even though the overall design was top-down. In the first stage, a maintenance mode version of the ladder diagrams and operator displays was implemented on a device by device basis as hardware was being installed in the plant. This version allowed operators to exercise various features of the equipment, with only essential interlocks operating for the protection of manually operated devices and ensure staff safety. Various faults were introduced to the control blocks under test by placing jumper wires or forcing relays in the PLC to a particular state to test for proper behaviour of the logic circuitry. Device manipulation was controlled from the associated computer screens or from local panels. Progressively more interlocks and display logic were added to create the run mode logic and displays.

6.2 Overview of Displays

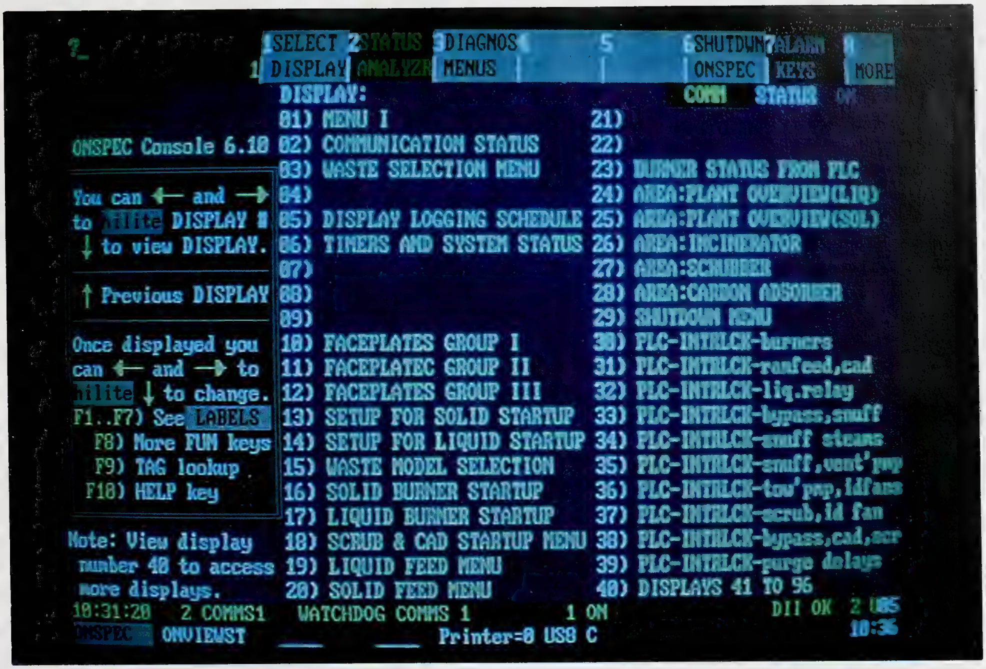
Screens are organized in various functional groups, as follows:

- Start-up and overall system set-up screens
- Overall plant or unit/area process displays
- Information on interlocks
- Controller set-up and tuning screens
- Control group displays
- Shut-down displays
- Help screens on uses of PID'S commands, tags, various system commands, alarms etc.

Some of the above are a part of the ONSPEC™ software.

Figures 13 and 14 show the ONSPEC™ screens that give listings of displays available to the operator.

All ONSPEC™ displays were designed for the operators' convenience and ease of performing tasks. Not all desired features were implemented; for example, it was not possible to include a feature enabling the plant operator to go directly to the appropriate screen associated with a given alarm to view the process display before acknowledging the alarm. Other ideas were not as useful as they initially appeared; such as, a "model" set-up screen, which is described in more detail later. The lack of effective batch ramping features of ONSPEC™ software limited the usefulness of these pre-configured process set-ups.



```
?_
                                DISPLAY:
                                01) MENU I                          21)
ONSPEC Console 6.10             02) COMMUNICATION STATUS            22)
                                03) WASTE SELECTION MENU            23) BURNER STATUS FROM PLC
You can ← and →                 04)                                 24) AREA:PLANT OVERVIEW(LIQ)
to hilite DISPLAY #             05) DISPLAY LOGGING SCHEDULE        25) AREA:PLANT OVERVIEW(SOL)
 ↓ to view DISPLAY.             06) TIMERS AND SYSTEM STATUS        26) AREA:INCINERATOR
                                07)                                 27) AREA:SCRUBBER
 ↑ Previous DISPLAY             08)                                 28) AREA:CARBON ADSORBER
                                09)                                 29) SHUTDOWN MENU
Once displayed you              10) FACEPLATES GROUP I              30) PLC-INTRLCK-burners
can ← and → to                  11) FACEPLATEC GROUP II             31) PLC-INTRLCK-ramfeed,cad
hilite ↓ to change.             12) FACEPLATES GROUP III            32) PLC-INTRLCK-liq.relay
F1..F7) See LABELS              13) SETUP FOR SOLID STARTUP         33) PLC-INTRLCK-bypass,snuff
  F8) More FUN keys             14) SETUP FOR LIQUID STARTUP        34) PLC-INTRLCK-snuff steams
  F9) TAG lookup                15) WASTE MODEL SELECTION           35) PLC-INTRLCK-snuff,vent'pmp
 F10) HELP key                  16) SOLID BURNER STARTUP            36) PLC-INTRLCK-tow'pmp,idfans
                                17) LIQUID BURNER STARTUP           37) PLC-INTRLCK-scrub,id fan
Note: View display              18) SCRUB & CAD STARTUP MENU        38) PLC-INTRLCK-bypass,cad,scr
 number 40 to access            19) LIQUID FEED MENU                39) PLC-INTRLCK-purge delays
 more displays.                 20) SOLID FEED MENU                 40) DISPLAYS 41 TO 96
10:31:20   2 COMMS1   WATCHDOG COMMS 1          1 ON                DII OK  2 U85
ONSPEC  ONVIEWST   ____  ____  Printer=0 US8 C                                10:36
```

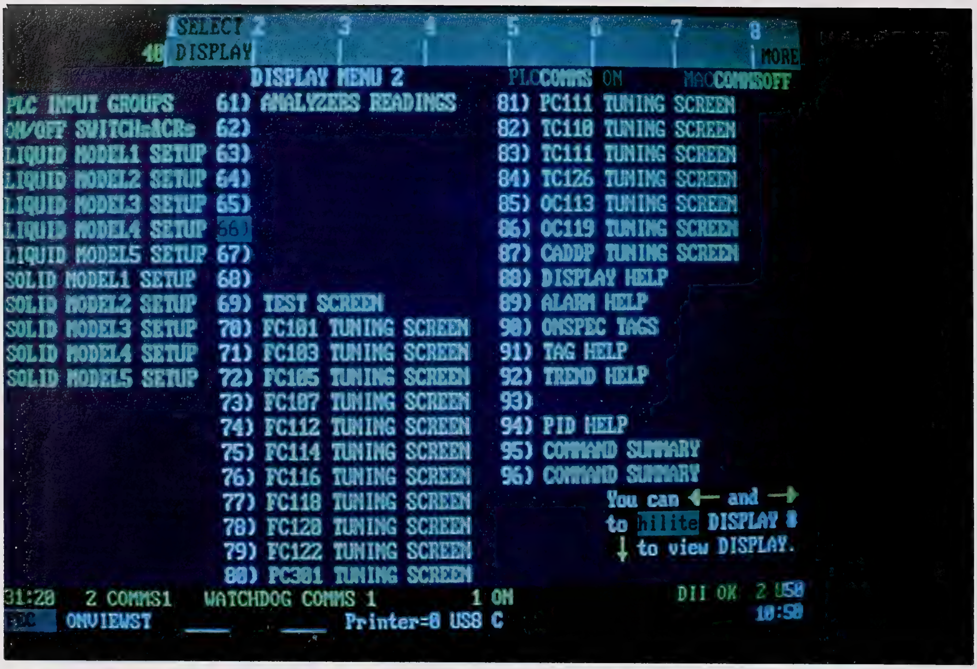
Figure 13   Screen 1: MENU 1, Displays 1 - 40

The operator Interface System consists of two networked PCs that are functionally specialised: one of these is for the process control and the other is for data analysis and monitoring of experimental progress. There are screen variations available on these computers. Operator interface screens available on the control computer and their use during routine runs are described later.

6.3 Communication

As mentioned above, the current system consists of two PCs interconnected by ARC-NET. In addition, four remote terminals can be connected via serial lines to access the ONSPEC™ screens and data. This arrangement provides physical separation of plant operators monitoring equipment, from scientists conducting experiments, performing on-line monitoring, or analyzing experimental data. Staff interested in an experiment can access data through remote consoles.

Additionally, ONSPEC™ communicates with the Westinghouse and TI (MACSYM replacement) PLCs. The refresh rate of screens is approximately 5 seconds. This matches the



You can ← and → to hilite DISPLAY # ↓ to view DISPLAY.

Figure 14 Screen 40: MENU 2, Displays 41 - 96

rate at which ONSPEC™ interrogates PLCs to update the data base. There are two types of data points: one type is always being requested, independent of the currently invoked screen; the other type is requested from the PLCs only when required for the currently activated screen. When a data point is placed on a receive queue, it is first compared with the currently stored value. If it has the same value, the point is removed from the queue; otherwise, it is processed by checking for alarm conditions, clamp limits etc. An example of data requested on demand is the controller tuning display (see screen 75; Figure 23). Tuning parameters are needed only when an operator recalls this screen. Normally, these parameters, residing in the PLCs are not required by ONSPEC™ and therefore do not need to be transmitted every time the screen is refreshed. For illustration purposes, fragments of a PLC communication configuration file are listed below:

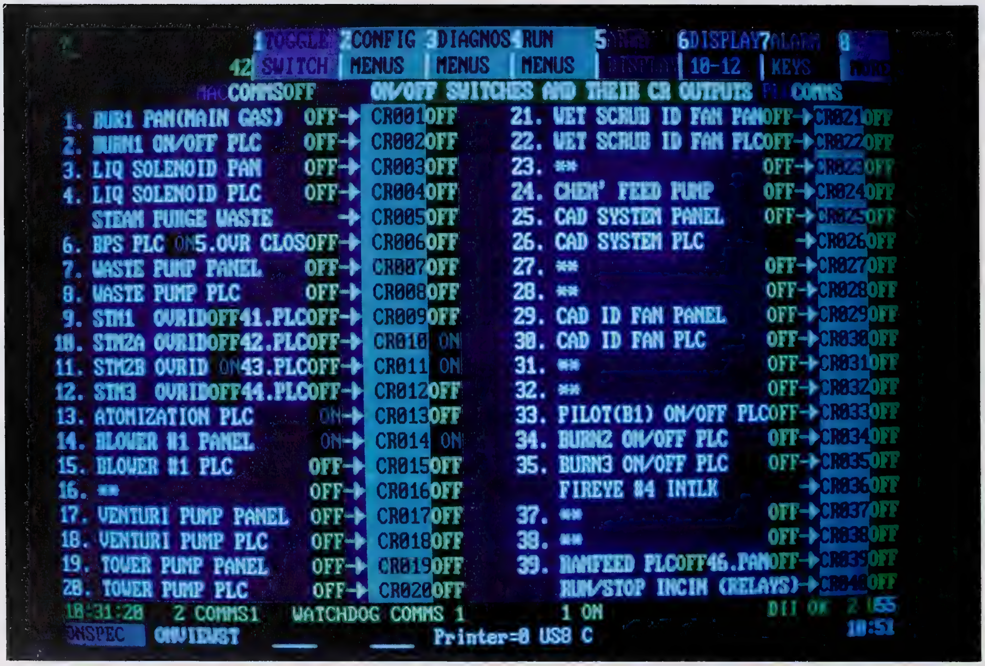
```
; CONTROL BLOCK FACEPLATES GROUP I
7,B10   HR1104   EUR 511  *  Per 100   1023 ;    FC101 SETPOINT VALUE
6,B10   HR1265   EUR 513  *  Per 100   1023 ;    OUTPUT VALUE OF CONTROLLER
5,B10   HR0032   EUI 341                    ;    CONTR OUTPUT STATUS WORD
7,B10   HR1105   EUR 514  *  Per 100   1023 ;    FC103 SETPOINT VALUE
6,B10   HR1266   EUR 516  *  Rev 100   1023 ;    reverse action OUTPUT value
5,B10   HR0064   EUI 342                    ;    CONTR OUTPUT STATUS WORD
7,B10   HR1106   EUR 517  *  Per 100   1023 ;    FC105 SETPOINT VALUE
6,B10   HR1267   EUR 519  *  Per 100   1023 ;    OUTPUT VALUE OF CONTROLLER
5,B10   HR0096   EUI 343                    ;    CONTR OUTPUT STATUS WORD
7,B10   HR1107   EUR 520  *  Per 100   1023 ;    FC107 SETPOINT VALUE
7,B10   HR0621   EUR 623  *  Per 100   1023 ;    FC107 CONDITIONED SETPOINT
6,B10   HR1268   EUR 522  *  Per 100   1023 ;    OUTPUT VALUE OF CONTROLLER
5,B10   HR0128   EUI 344                    ;    CONTR OUTPUT STATUS WORD
7,B10   HR1116   EUR 547  *  Temp 50   1023 ;    TC110 SETPOINT VALUE
6,B10   HR1252   EUR 549  *  Per 100   1023 ;    OUTPUT VALUE OF CONTROLLER
5,B10   HR0416   EUI 353                    ;    CONTR OUTPUT STATUS WORD
7,B10   HR1119   EUR 556  *  Per 100   1023 ;    OC113 SETPOINT VALUE
6,B10   HR1255   EUR 558  *  Per 100   1023 ;    OUTPUT VALUE OF CONTROLLER
5,B10   HR0512   EUI 356                    ;    CONTR OUTPUT STATUS WORD
```

A typical line of this configuration file describes with which screen, data is to be associated, how often it is to be requested, what conversion functions are to be applied, and if a particular data point is to be sent or received.

Every communication link is monitored by an associated watchdog program. The status of the link is crucial for data correctness on the screen; therefore the status is displayed on every screen together with the operating status of the PLC. During initial stages of implementation, when the system was not optimised for communication efficiency and the hardware was slow, there were problems of overloading communications queues thus, we implemented a feature to monitor for this overloading. This feature was used during the initial stages and is now switched off during normal runs.

6.4 Start-up and Overall System Set-up Screens

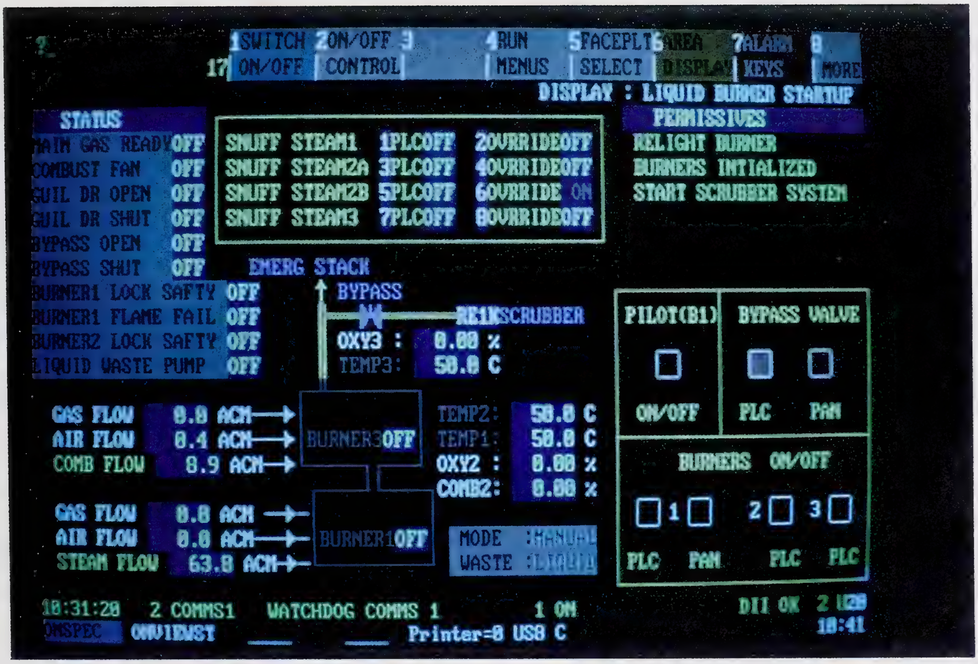
After checking communication status between controls system hardware, the operator selects a mode of operation: liquid or solid waste. This selection enables or disables various sections of the PLC ladder diagrams and chooses the required controllers. The switching on of devices is usually performed from screen 42, shown in Figure 15.



```
               MACCOMMSOFF     ON/OFF SWITCHES AND THEIR CR OUTPUTS PLCCOMMS
 1. BUR1 PAN(MAIN GAS)  OFF→ CR001OFF     21. WET SCRUB ID FAN PANOFF→CR021OFF
 2. BURN1 ON/OFF PLC    OFF→ CR002OFF     22. WET SCRUB ID FAN PLCOFF→CR022OFF
 3. LIQ SOLENOID PAN    OFF→ CR003OFF     23. **                  OFF→CR023OFF
 4. LIQ SOLENOID PLC    OFF→ CR004OFF     24. CHEM' FEED PUMP     OFF→CR024OFF
    STEAM PURGE WASTE      → CR005OFF     25. CAD SYSTEM PANEL    OFF→CR025OFF
 6. BPS PLC ON5.OVR CLOSOFF→ CR006OFF     26. CAD SYSTEM PLC         →CR026OFF
 7. WASTE PUMP PANEL    OFF→ CR007OFF     27. **                  OFF→CR027OFF
 8. WASTE PUMP PLC      OFF→ CR008OFF     28. **                  OFF→CR028OFF
 9. STM1  OVRIDOFF41.PLCOFF→ CR009OFF     29. CAD ID FAN PANEL    OFF→CR029OFF
10. STM2A OVRIDOFF42.PLCOFF→ CR010 ON     30. CAD ID FAN PLC      OFF→CR030OFF
11. STM2B OVRID ON43.PLCOFF→ CR011 ON     31. **                  OFF→CR031OFF
12. STM3  OVRIDOFF44.PLCOFF→ CR012OFF     32. **                  OFF→CR032OFF
13. ATOMIZATION PLC      ON→ CR013OFF     33. PILOT(B1) ON/OFF PLCOFF→CR033OFF
14. BLOWER #1 PANEL      ON→ CR014 ON     34. BURN2 ON/OFF PLC    OFF→CR034OFF
15. BLOWER #1 PLC       OFF→ CR015OFF     35. BURN3 ON/OFF PLC    OFF→CR035OFF
16. **                  OFF→ CR016OFF         FIREYE #4 INTLK        →CR036OFF
17. VENTURI PUMP PANEL  OFF→ CR017OFF     37. **                  OFF→CR037OFF
18. VENTURI PUMP PLC    OFF→ CR018OFF     38. **                  OFF→CR038OFF
19. TOWER PUMP PANEL    OFF→ CR019OFF     39. RAMFEED PLCOFF46.PANOFF→CR039OFF
20. TOWER PUMP PLC      OFF→ CR020OFF         RUN/STOP INCIN (RELAYS)→CR040OFF
10:31:20   2 COMMS1   WATCHDOG COMMS 1     1 ON               DII OK  2 U55
ONSPEC   ONVIEWST   ____   ____   Printer=0 US8 C                     10:51
```

Figure 15 Screen 42: On/Off Switches and Their CR Outputs

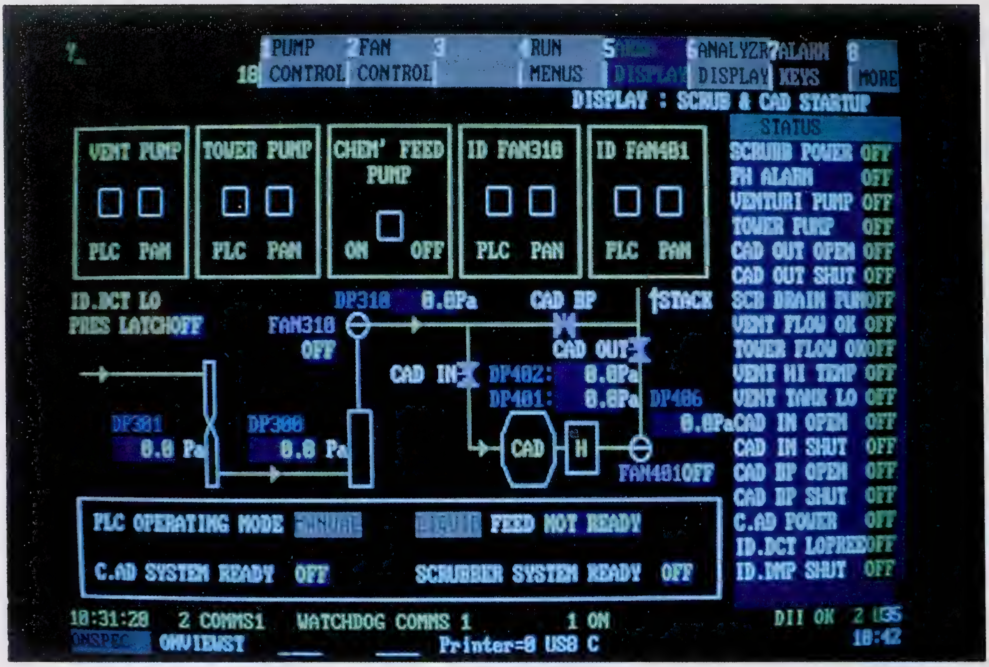
Toggling the on/off status on the screen causes activation of the relay responsible for the starting of the corresponding device. There is an overview screen that shows a summary of start-up set-ups of control blocks (not shown here). Burners, scrubber and carbon filter sections started from dedicated screens 17 and 18 shown in Figure 16 and Figure 17.



```
17
DISPLAY : LIQUID BURNER STARTUP

STATUS
MAIN GAS READY OFF
COMBUST FAN    OFF
GUIL DR OPEN   OFF
GUIL DR SHUT   OFF
BYPASS OPEN    OFF
BYPASS SHUT    OFF
BURNER1 LOCK SAFTY OFF
BURNER1 FLAME FAIL OFF
BURNER2 LOCK SAFTY OFF
LIQUID WASTE PUMP  OFF

SNUFF STEAM1  1PLCOFF 2OVRRIDEOFF
SNUFF STEAM2A 3PLCOFF 4OVRRIDEOFF
SNUFF STEAM2B 5PLCOFF 6OVRRIDE ON
SNUFF STEAM3  7PLCOFF 8OVRRIDEOFF

PERMISSIVES
RELIGHT BURNER
BURNERS INTIALIZED
START SCRUBBER SYSTEM

OXY3 :  0.00 %
TEMP3:  50.0 C

GAS FLOW    0.0 ACM
AIR FLOW    0.4 ACM
COMB FLOW   8.9 ACM
BURNER3 OFF

TEMP2:  50.0 C
TEMP1:  50.0 C
OXY2 :  0.00 %
COMB2:  0.00 %

GAS FLOW    0.0 ACM
AIR FLOW    0.0 ACM
STEAM FLOW  63.0 ACM
BURNER1 OFF

MODE  :MANUAL
WASTE :LIQUID

10:31:20  2 COMMS1  WATCHDOG COMMS 1   1 ON      DI1 OK  2 U20
ONSPEC  ONVIEWST          Printer=0 US0 C                10:41
```

Figure 16 Screen 17: Liquid Burner Start-up

With each screen are a few associated screens that can be accessed directly by pressing the corresponding function button. Available choices are shown at the top of the screen so the operator does not have to remember display numbers or go to an auxiliary screen to find one. In many cases, the basic control actions are assigned to the function keys so there is no need for the operator to tab to the proper display field to change one.



ID.DCT LO PRES LATCHOFF

DP318 0.0Pa

FAN318 OFF

DP402: 0.0Pa

DP401: 0.0Pa

DP406 0.0Pa

DP381 0.0 Pa

DP380 0.0 Pa

FAN481OFF

STATUS
SCRUBB POWER OFF
PH ALARM OFF
VENTURI PUMP OFF
TOWER PUMP OFF
CAD OUT OPEN OFF
CAD OUT SHUT OFF
SCR DRAIN PUMOFF
VENT FLOW OK OFF
TOWER FLOW OKOFF
VENT HI TEMP OFF
VENT TANK LO OFF
CAD IN OPEN OFF
CAD IN SHUT OFF
CAD BP OPEN OFF
CAD BP SHUT OFF
C.AD POWER OFF
ID.DCT LOPRESOFF
ID.DMP SHUT OFF

PLC OPERATING MODE MANUAL

LIQUID FEED NOT READY

C.AD SYSTEM READY OFF

SCRUBBER SYSTEM READY OFF

18:31:28 2 COMMS1 WATCHDOG COMMS 1 1 ON

ONSPEC ONVIEWST Printer=0 US0 C

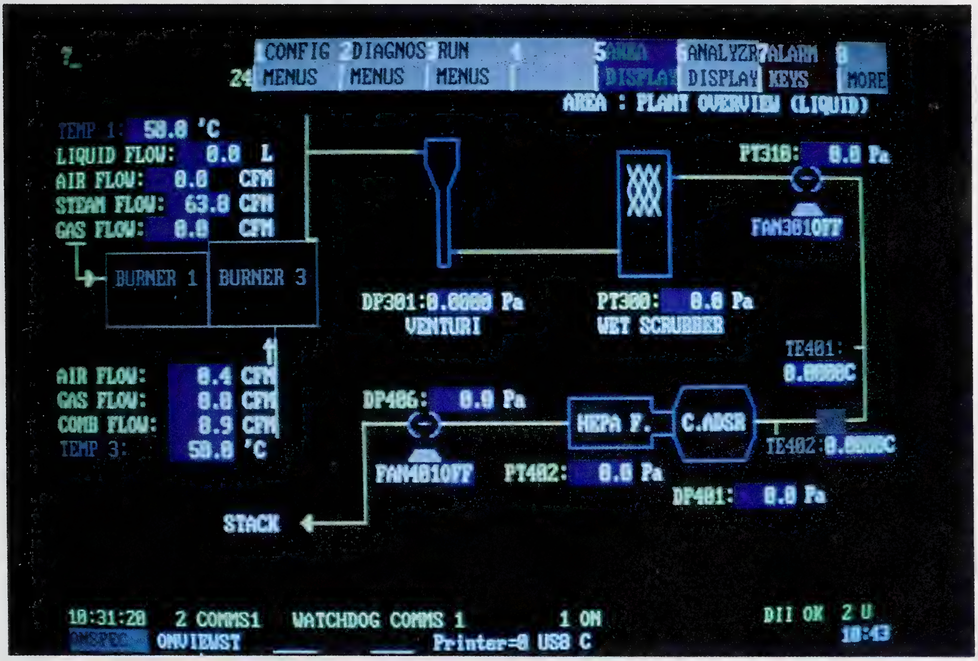
DII OK 2 U35 18:42

Figure 17 Screen 18: Scrubber and CAD (Carbon Adsorber) Start-up

The start-up process is manual. Gradual heating of chambers requires flexible set-up for ramping of temperatures, a feature not currently provided by the system (it would require an extensive programming effort). For the "single button" capability to start-up or shut-down the plant, a ramping feature would be required to work with the operating "model set-up" screens.

6.5 Overall Plant or Unit/Area Process Displays

Another class of displays has been designed to provide a comprehensive view of the plant status during normal operation. Screen 24 (Figure 18) shows the display presenting the plant overview. Graphic symbols represent major areas of the plant and text indicates equipment status and important process values.



AREA : PLANT OVERVIEW (LIQUID)

TEMP 1: 50.0 'C
LIQUID FLOW: 0.0 L
AIR FLOW: 0.0 CFM
STEAM FLOW: 63.0 CFM
GAS FLOW: 0.0 CFM

AIR FLOW: 0.4 CFM
GAS FLOW: 0.0 CFM
COMB FLOW: 0.9 CFM
TEMP 3: 50.0 'C

DP301:0.0000 Pa
PT300: 0.0 Pa
PT310: 0.0 Pa
FAN301OFF
TE401: 0.0000C
DP406: 0.0 Pa
FAN401OFF
PT402: 0.0 Pa
TE402:0.0000C
DP401: 0.0 Pa

10:31:20 2 COMMS1 WATCHDOG COMMS 1 1 ON DII OK 2 U
OMSPEC ONVIEWST Printer=0 US0 C 10:43

Figure 18 Screen 24: Plant Overview - Liquid Mode

For more detailed information, an operator can switch to various plant area displays. Screen 26 (Figure 19) is an example of the plant area display, in this case, incinerator burners. Similar screens display the carbon adsorber area (Figure 20, screen 28) etc.

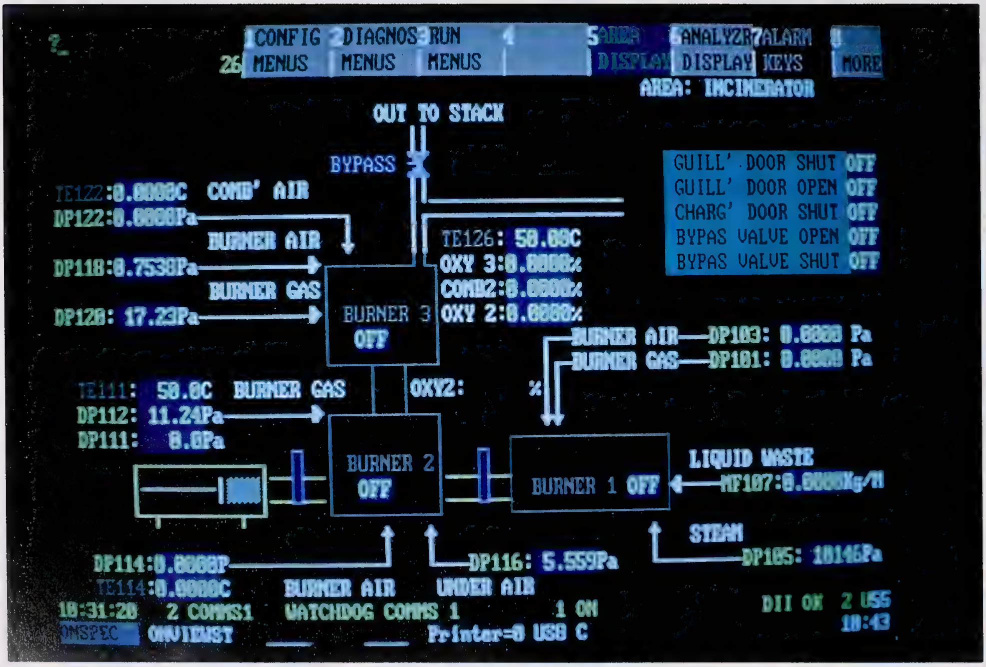
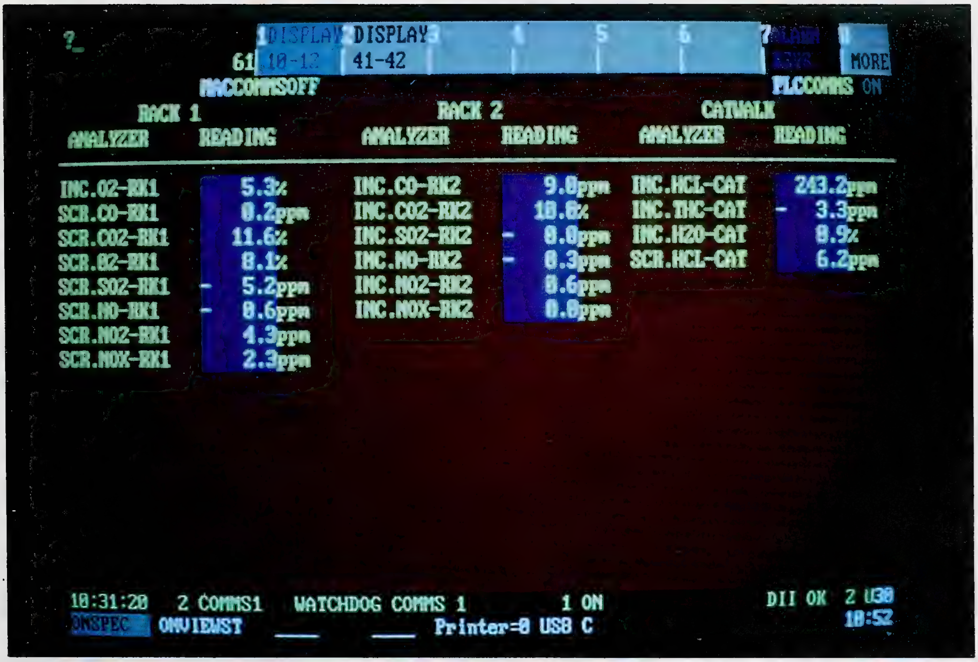


Figure 19 Screen 26: Incinerator

Readings of various analyzers are summarized on a separate screen, with additional screens to enter conversion coefficients. See Figure 20, screen 61 below.



MACCOMMSOFF

PLCCOMMS ON

RACK 1		RACK 2		CATWALK	
ANALYZER	READING	ANALYZER	READING	ANALYZER	READING
INC.02-RK1	5.3%	INC.CO-RK2	9.0ppm	INC.HCL-CAT	243.2ppm
SCR.CO-RK1	0.2ppm	INC.CO2-RK2	10.6%	INC.THC-CAT	- 3.3ppm
SCR.CO2-RK1	11.6%	INC.SO2-RK2	- 0.0ppm	INC.H2O-CAT	0.9%
SCR.02-RK1	0.1%	INC.NO-RK2	- 0.3ppm	SCR.HCL-CAT	6.2ppm
SCR.SO2-RK1	- 5.2ppm	INC.NO2-RK2	0.6ppm		
SCR.NO-RK1	- 0.6ppm	INC.NOX-RK2	0.0ppm		
SCR.NO2-RK1	4.3ppm				
SCR.NOX-RK1	2.3ppm				

10:31:20 2 COMMS1 WATCHDOG COMMS 1 1 ON DII OK 2 U30
ONSPEC ONVIEWST ____ ____ Printer=0 USB C 10:52

Figure 20 Screen 61: Analyser Readings

Substantial efforts have achieved automated readings from analyzers. In many cases, special circuitry added to the instrument enables the computer to read the position of the panel range switches. The initial concept requiring the operator to enter scaling factors when switching ranges did not work because of inconvenience and uncertainty with the correctness of computer readouts.

6.6 Information on Interlocks

During startup and normal operation some interlocks may be triggered. These interlocks might shut-down some equipment or might not allow some other devices to be activated. Active interlocks generate alarm messages, but this information is often not sufficient to help an operator restart the plant. To aid an operator in identifying reasons for the interlock activation, several screens have been designed to show the status of contacts leading to the relay trigger. An example of such a screen is shown below in Figure 21.

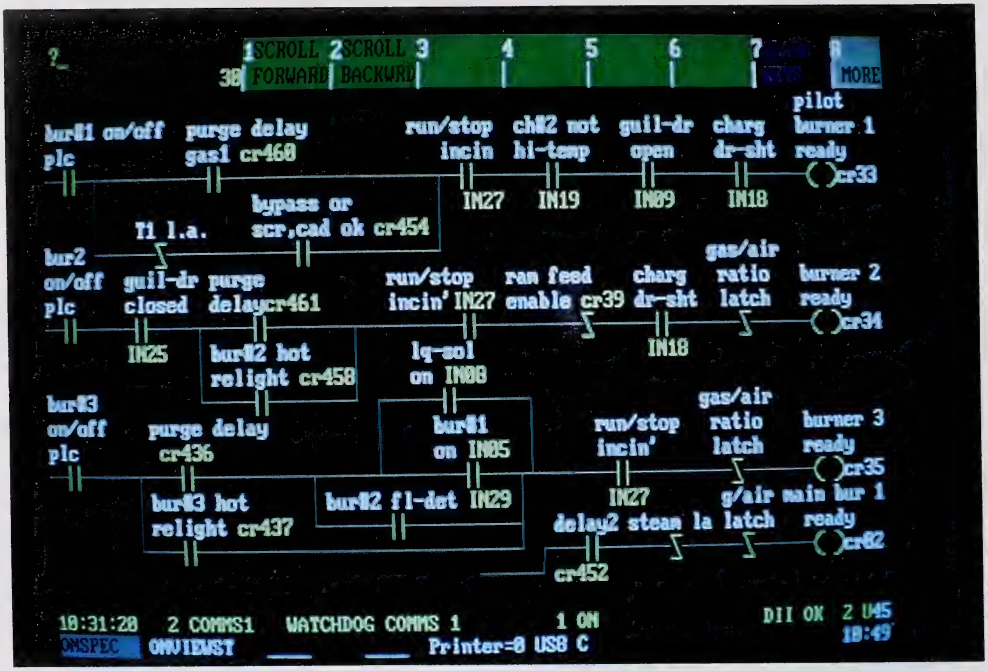


Figure 21 Screen 30: PLC Interlock - Burners

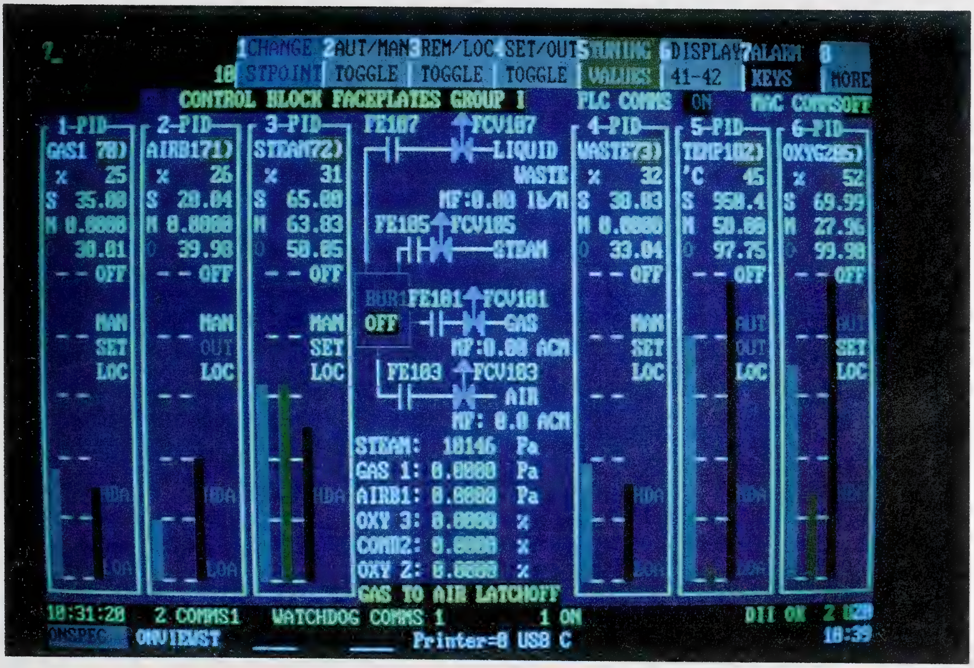
In this example, screen 30 displays the status of the logic required to bring burners 1, 2 and 3 into a ready state. Symbols of contacts change shape according to their state (opened or closed). The operator can thus determine the condition that caused the interlock to activate.

Alternatively, in more difficult cases, a qualified engineer can interrogate the status of the relays of the PLC, or, for diagnostic purposes, force a contact change by using the PLC program loader, which communicates with the PLC on a second channel concurrently with the ONSPEC™ software. This method has been used occasionally, especially during plant commissioning and startup.

The described displays show only the current logic state. To trace switching sequences leading to the interlock trip, the operator can build a trend display and select tags of interest for trending. There is no comprehensive automatic diagnostic with trace capabilities built into the system because the effort was not warranted.

6.7 Control Group Displays

During start-up, some control loops must be set to manual mode. A good example is the oxygen control loop. The oxygen probe must be heated to operating temperature before readings become meaningful, thus, the automatic control up to this point must be disabled. To help the operator switch controls to local/remote or manual/automatic, the controls have been collected into groups. Figure 22, screen 10, shown below, displays a typical layout of such a control group.



STEAM: 10146 Pa
GAS 1: 0.0000 Pa
AIRB1: 0.0000 Pa
OXY 3: 0.0000 %
COMM2: 0.0000 %
OXY 2: 0.0000 %
GAS TO AIR LATCHOFF

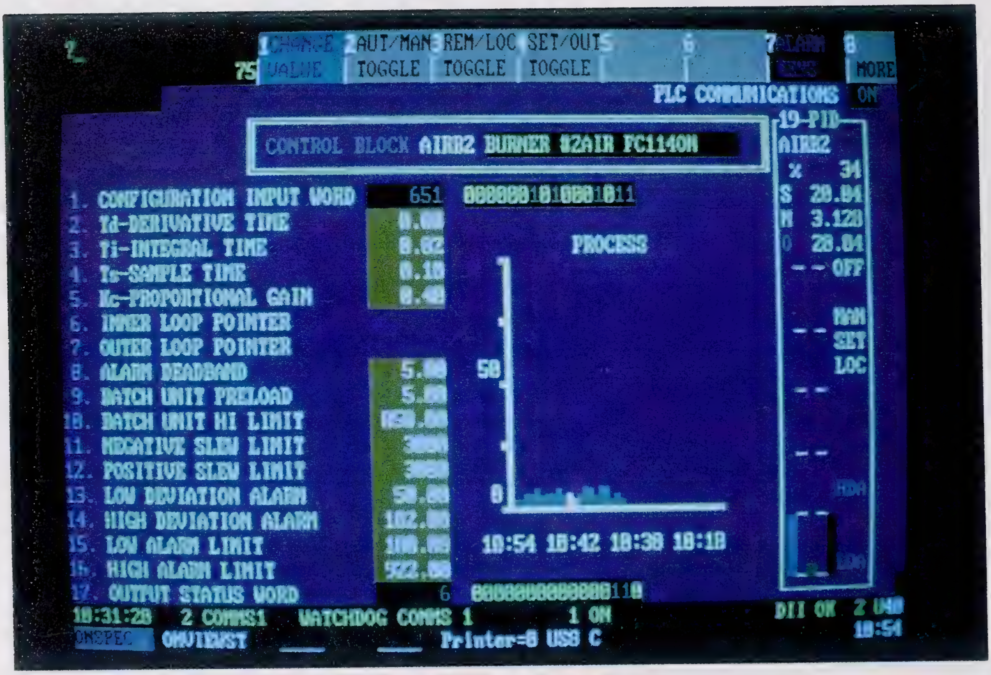
10:31:20 2 COMMS1 WATCHDOG COMMS 1 1 ON DII OK 2 U20
ONSPEC ONVIEWST Printer=0 USB C 10:39

Figure 22 Screen 10: Control Block, Group 1

In addition, input and output tracking automates, as much as possible, switching of controllers between local and cascade mode of operations.

6.8 Controller Setup and Tuning Screens

Every controller in the PLC has a corresponding tuning screen in the ONSPEC™ enabling various controller parameters to be set. A typical arrangement is shown in Figure 23, screen 75 below.



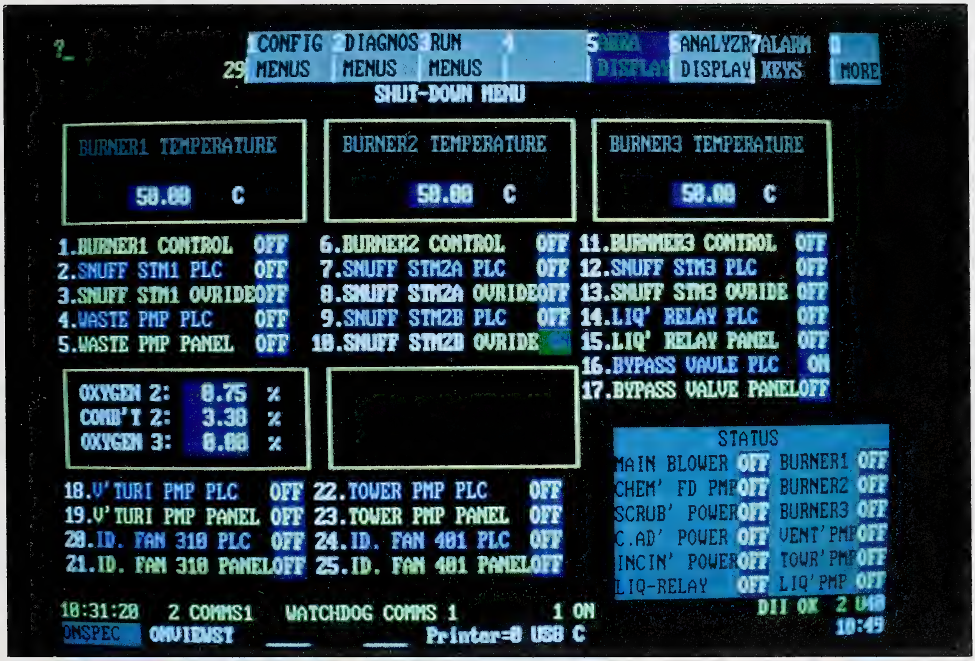
```
CONTROL BLOCK AIR02 BURNER #2AIR FC1140M

 1. CONFIGURATION INPUT WORD        651  0000001010000011
 2. Td-DERIVATIVE TIME             0.00
 3. Ti-INTEGRAL TIME               0.02
 4. Ts-SAMPLE TIME                 0.10
 5. Kc-PROPORTIONAL GAIN           0.40
 6. INNER LOOP POINTER
 7. OUTER LOOP POINTER
 8. ALARM DEADBAND                 5.00
 9. BATCH UNIT PRELOAD             5.00
10. BATCH UNIT HI LIMIT        [illegible]
11. NEGATIVE SLEW LIMIT        [illegible]
12. POSITIVE SLEW LIMIT        [illegible]
13. LOW DEVIATION ALARM           50.00
14. HIGH DEVIATION ALARM         102.00
15. LOW ALARM LIMIT              100.00
16. HIGH ALARM LIMIT             522.00
17. OUTPUT STATUS WORD                6  0000000000000110
10:31:20   2 COMMS1   WATCHDOG COMMS 1         1 ON        DII OK  2 U40
ONSPEC  ONVIEWST                     Printer=0 US0 C               10:54
```

Figure 23 Screen 75: Tuning Loop for FC114 Controller

The screen has been divided into 3 functional regions. On the left side, configurable parameters are listed with corresponding values. The operator moves the cursor to an appropriate field and modifies its value. The centre is dedicated to trend display and serves as an aid in visualisation of the control loop performance. On the right, a controller faceplate that displays control values and status indicators, is used for manipulation.

6.9 Shut-Down Display

The shut-down screen, shown in Figure 24 helps the operator with shut-down. This check list is useful for shutting the plant down in an orderly way.



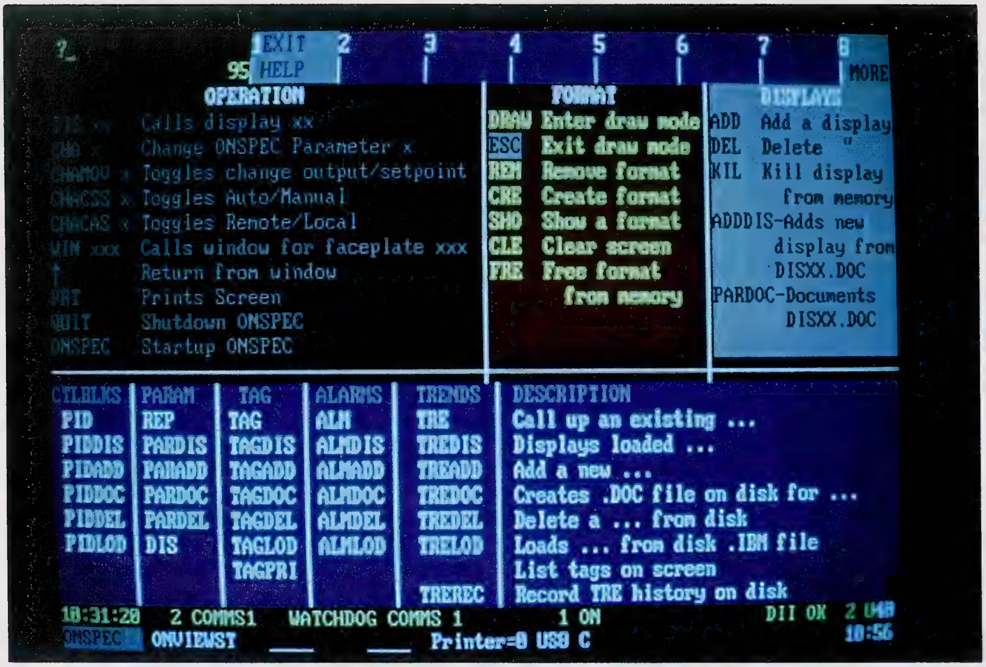
```
SHUT-DOWN MENU

BURNER1 TEMPERATURE      BURNER2 TEMPERATURE      BURNER3 TEMPERATURE
     50.00  C                 50.00  C                 50.00  C

1.BURNER1 CONTROL  OFF   6.BURNER2 CONTROL   OFF 11.BURNER3 CONTROL  OFF
2.SNUFF STM1 PLC   OFF   7.SNUFF STM2A PLC   OFF 12.SNUFF STM3 PLC   OFF
3.SNUFF STM1 OVRIDEOFF   8.SNUFF STM2A OVRIDEOFF 13.SNUFF STM3 OVRIDE OFF
4.WASTE PMP PLC    OFF   9.SNUFF STM2B PLC   OFF 14.LIQ' RELAY PLC   OFF
5.WASTE PMP PANEL  OFF  10.SNUFF STM2B OVRIDE    15.LIQ' RELAY PANEL OFF
                                                 16.BYPASS VAVLE PLC  ON
OXYGEN 2:   0.75  %                              17.BYPASS VALVE PANELOFF
COMB'T 2:   3.30  %
OXYGEN 3:   0.00  %                                         STATUS
                                                   MAIN BLOWER OFF BURNER1 OFF
18.V'TURI PMP PLC   OFF 22.TOWER PMP PLC    OFF    CHEM' FD PMPOFF BURNER2 OFF
19.V'TURI PMP PANEL OFF 23.TOWER PMP PANEL  OFF    SCRUB' POWEROFF BURNER3 OFF
20.ID. FAN 310 PLC  OFF 24.ID. FAN 401 PLC  OFF    C.AD' POWER OFF VENT'PMPOFF
21.ID. FAN 310 PANELOFF 25.ID. FAN 401 PANELOFF    INCIN' POWEROFF TOWR'PMPOFF
                                                   LIQ-RELAY   OFF LIQ'PMP OFF
10:31:20   2 COMMS1   WATCHDOG COMMS 1          1 ON            DII OK  2 U40
ONSPEC  OMVIEWST  ____  ____  Printer=0 U80 C                         10:49
```

Figure 24 Screen 29: Shut-Down Menu

A one-button-initiated sequence to shut-down the plant was not workable, and was abandoned. This feature was similar in concept to the automatic start-up of the plant capability and required implementation of the "ramping feature". This feature would have allowed the operator to set a pre-programmed control of gradual cooling of the chambers with rates conforming to the cooling rates designated for our refractory.

6.10 Help Screens

In addition to the standard ONSPEC™ and concurrent DOS online help, a series of additional help screens provide on line help on the use of PIDs, commands, tags, various system commands, alarms etc. A good example of such a screen is screen 95, shown below.



```
                     OPERATION                              FORMAT              DISPLAYS
DIS xx     Calls display xx                     DRAW Enter draw mode   ADD  Add a display
CHG x      Change ONSPEC Parameter x            ESC  Exit draw mode    DEL  Delete   "
CHAMOU x   Toggles change output/setpoint       REM  Remove format     KIL  Kill display
CHACSS x   Toggles Auto/Manual                  CRE  Create format           from memory
CHACAS x   Toggles Remote/Local                 SHO  Show a format     ADDDIS-Adds new
WIN xxx    Calls window for faceplate xxx       CLE  Clear screen           display from
↑          Return from window                   FRE  Free format             DISXX.DOC
PRT        Prints Screen                              from memory      PARDOC-Documents
QUIT       Shutdown ONSPEC                                                    DISXX.DOC
ONSPEC     Startup ONSPEC

CTLBLKS | PARAM  |  TAG   | ALARMS |  TRENDS | DESCRIPTION
 PID    | REP    | TAG    | ALM    |  TRE    | Call up an existing ...
 PIDDIS | PARDIS | TAGDIS | ALMDIS |  TREDIS | Displays loaded ...
 PIDADD | PARADD | TAGADD | ALMADD |  TREADD | Add a new ...
 PIDDOC | PARDOC | TAGDOC | ALMDOC |  TREDOC | Creates .DOC file on disk for ...
 PIDDEL | PARDEL | TAGDEL | ALMDEL |  TREDEL | Delete a ... from disk
 PIDLOD | DIS    | TAGLOD | ALMLOD |  TRELOD | Loads ... from disk .IBM file
        |        | TAGPRI |        |         | List tags on screen
        |        |        |        |  TREREC | Record TRE history on disk
10:31:20   2 COMMS1   WATCHDOG COMMS 1          1 ON                DII OK  2 U48
ONSPEC  ONVIEWST  ____   ____   Printer=0 US0 C                          10:56
```

Figure 25 Screen 95: Command Summary

This sample screen illustrates well the technique that helps an operator with system commands. The screen area has been divided into several regions, each associated with a different class of commands. The bottom section of this screen shows how certain ONSPEC™ commands are built. In the upper part is a description of selected system commands organized into groups.

Other help screens are built in similar ways by grouping related information in one region.

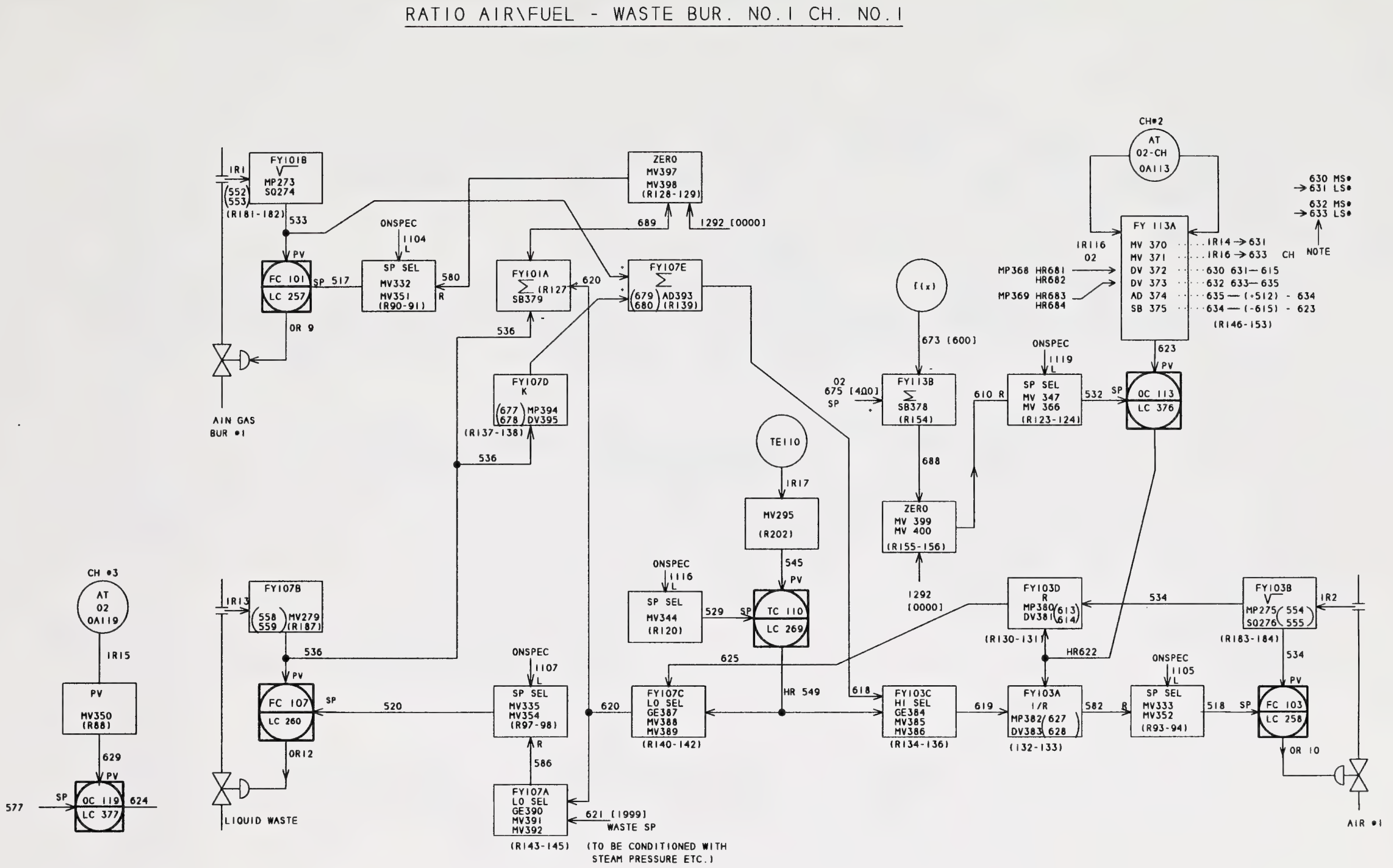
7 CONCLUDING REMARKS

In February 1993, installation of the additional incineration chamber, identified as chamber #4, was completed. The control and data acquisition system underwent substantial changes to accommodate this addition, even though the structure of individual control loops was merely a copy of the existing arrangements for chamber #3. This situation arose from the lack of available analog channels and free slots in the Westinghouse PLC. We incorporated the expansion by using the recently added TI 545 PLC (MACSYM replacement).

The combination of the PLC based control system with an IBM-PC based operator interface has proven to be a reliable and cost effective solution to pilot-scale plants like the Research Incineration Facility at AEC. Real time control applications, built on top of operating systems like OS/2 or even MS Windows or Windows NT, will help overcome the limitations of DOS and will provide easy, vendor independent, interprogram data exchange using DDE (Dynamic Data Exchange) or OLE (Object Linking and Embedding) functions. This is especially important in a research environment, where funds are decreasing and requirements remain extremely varied.

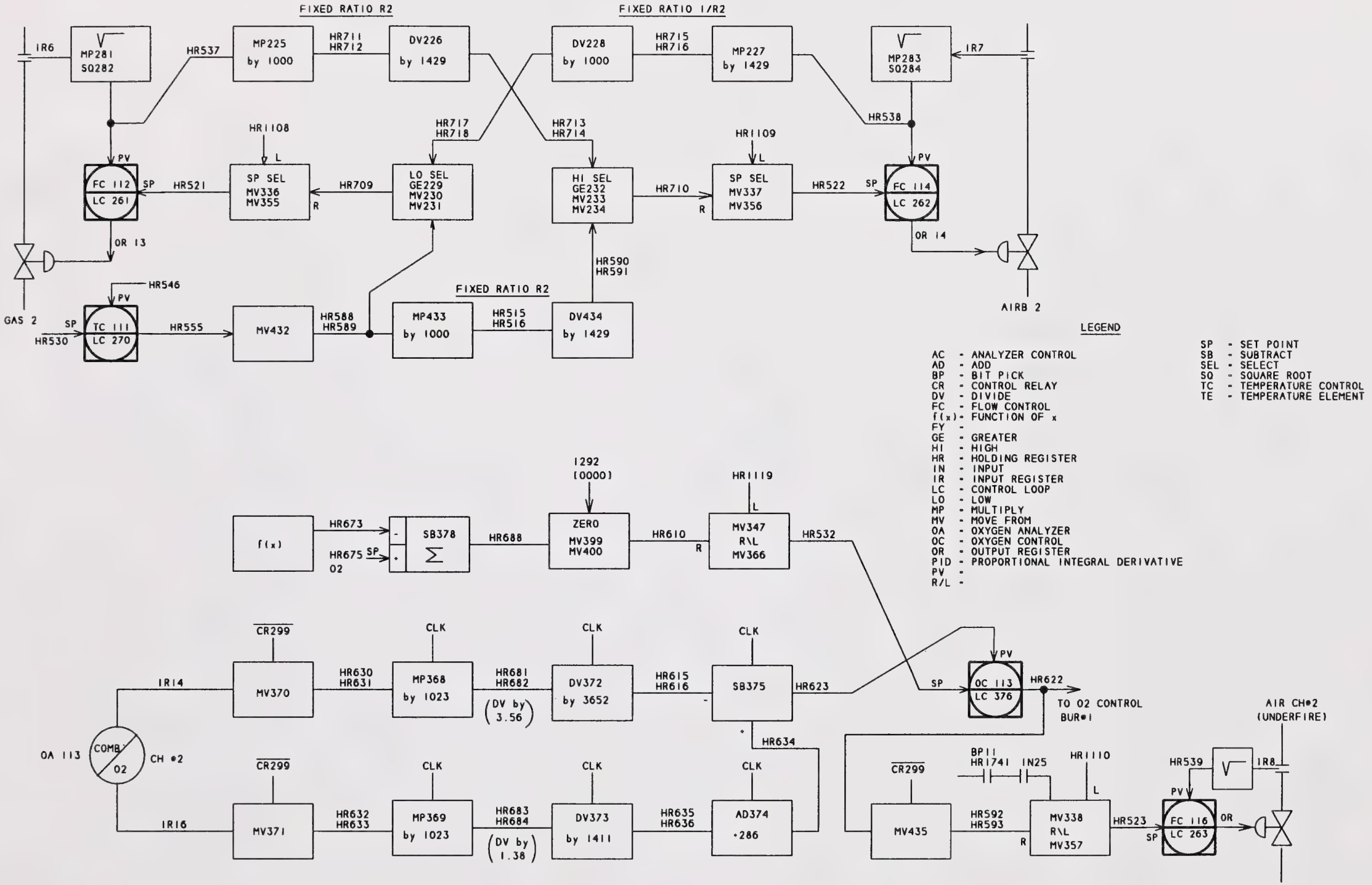
8 APPENDICES

A. Air/Fuel ratio control - chamber #1
B. Air/Gas ratio control - chamber #2
C. Air/Gas ratio control - chamber #3
D. Air/Gas ratio control - chamber #4
E. Air control select - chamber #3/chamber #4
F. Incinerator Venturi tank pH control



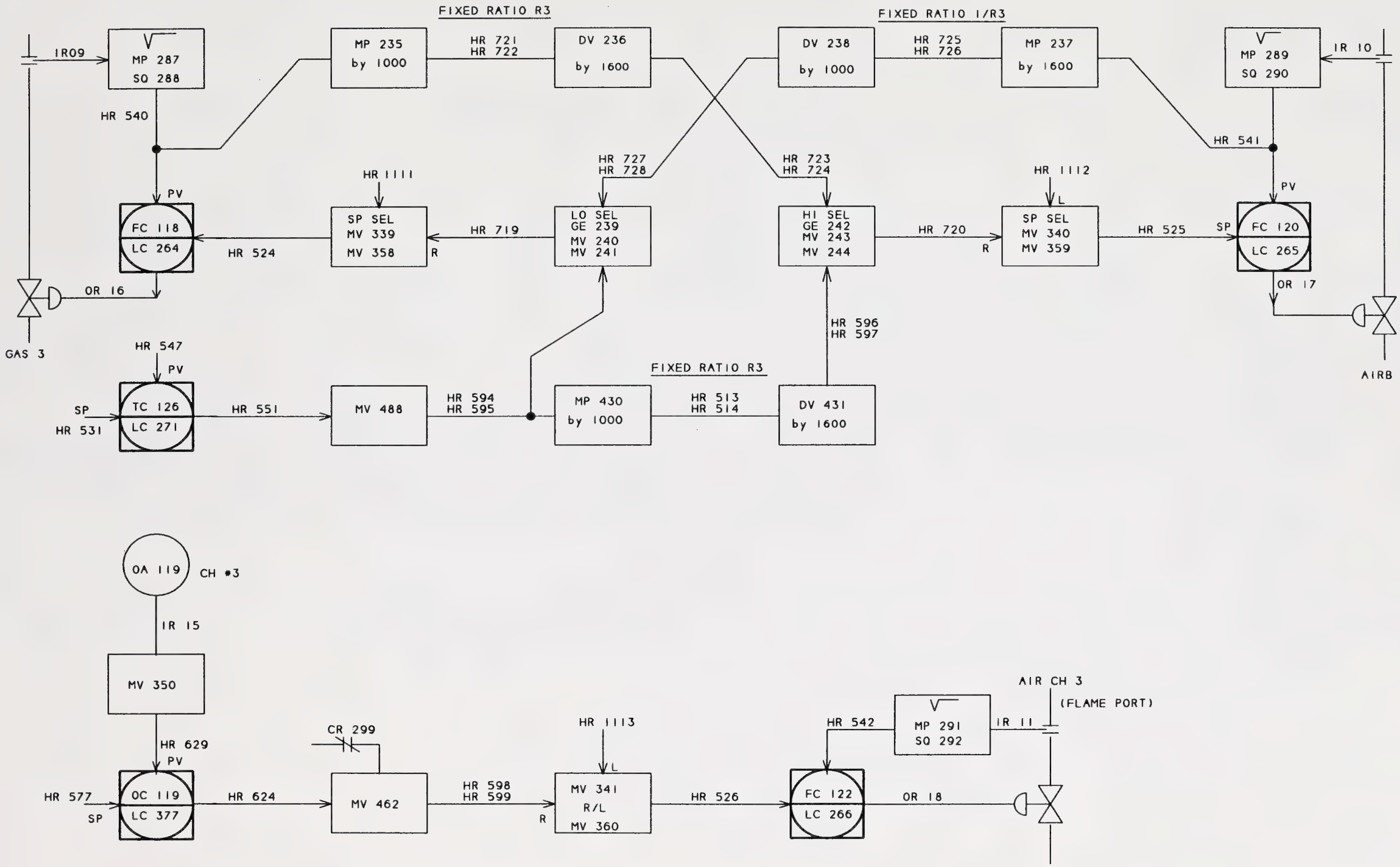
APPENDIX A: AIR/FUEL RATIO CONTROL - CHAMBER #1

AIR-GAS RATIO & O2 CONTROL CHAMBER NO.2 SOLID MODE (ANTI-SMOKE)

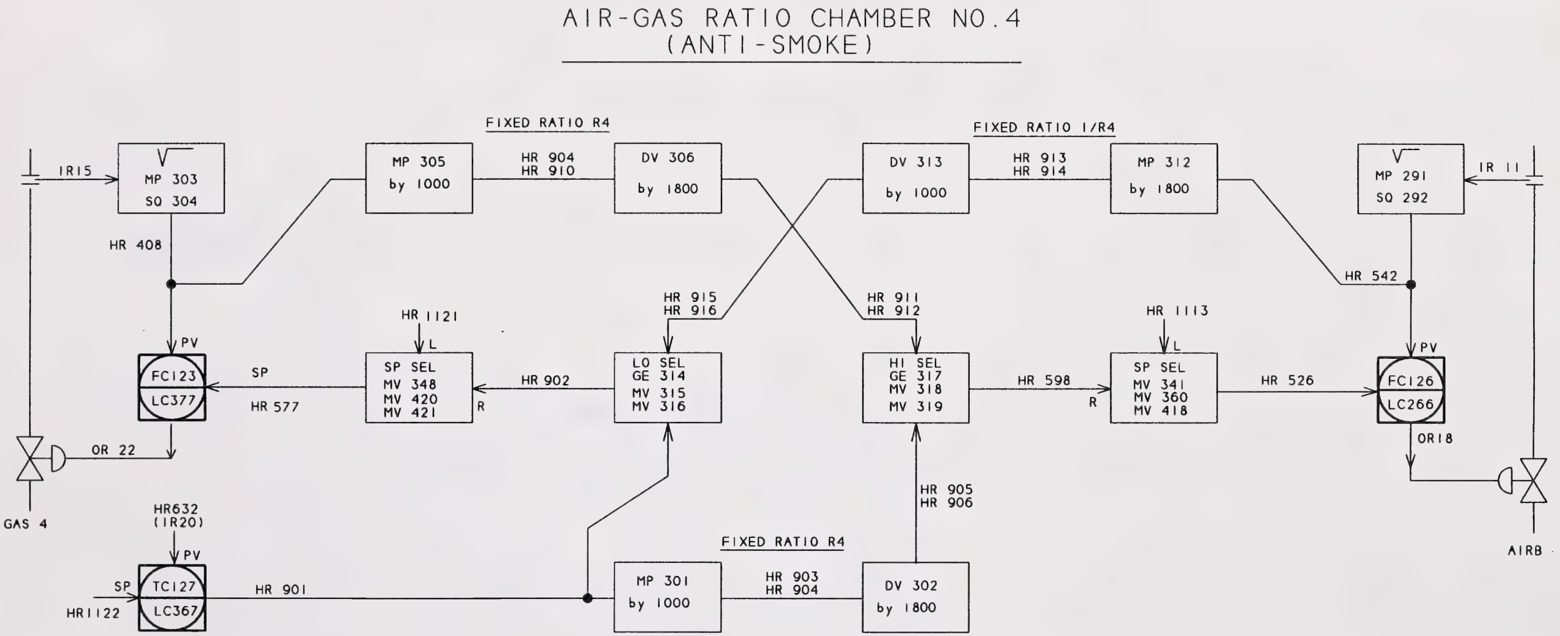


APPENDIX B: AIR/GAS RATIO CONTROL - CHAMBER #2

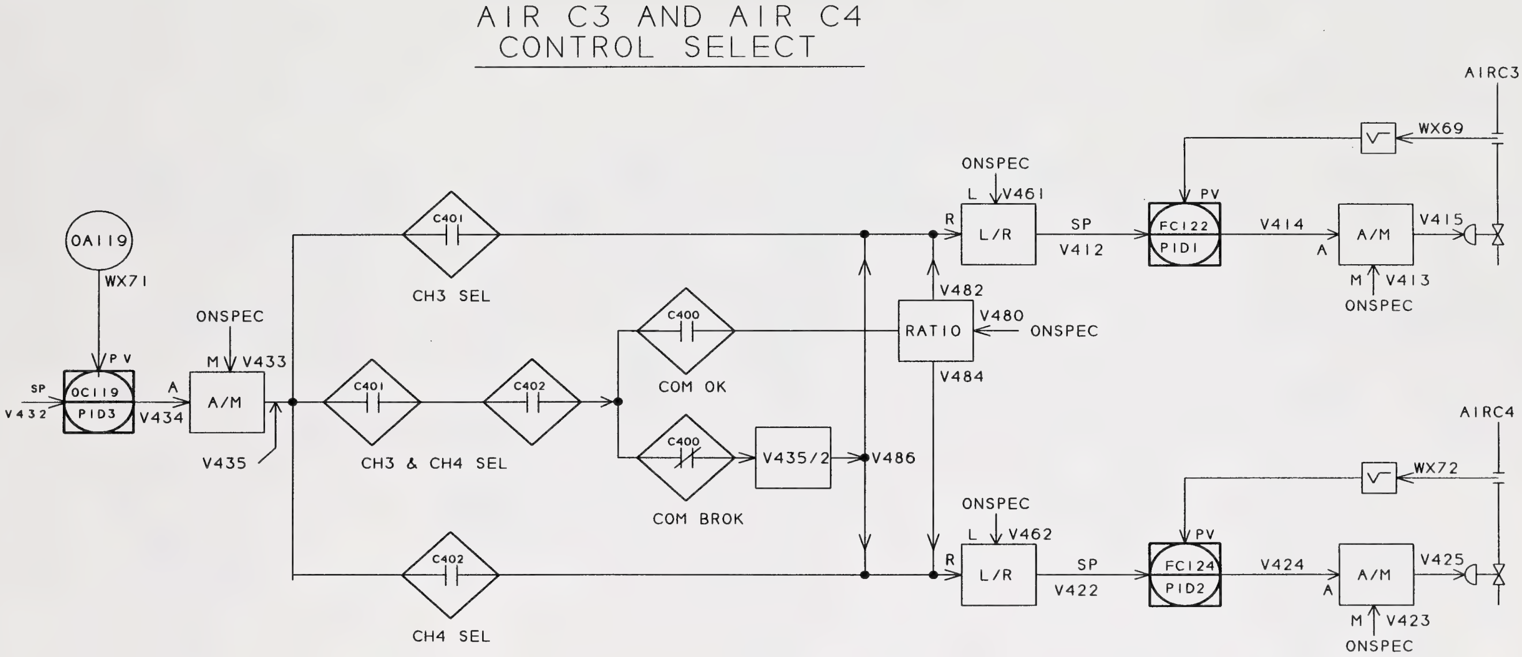
AIR-GAS RATIO CHAMBER NO. 3
(ANTI-SMOKE) LIQUID AND SOLID MODES.



APPENDIX C: AIR/GAS RATIO CONTROL - CHAMBER #3

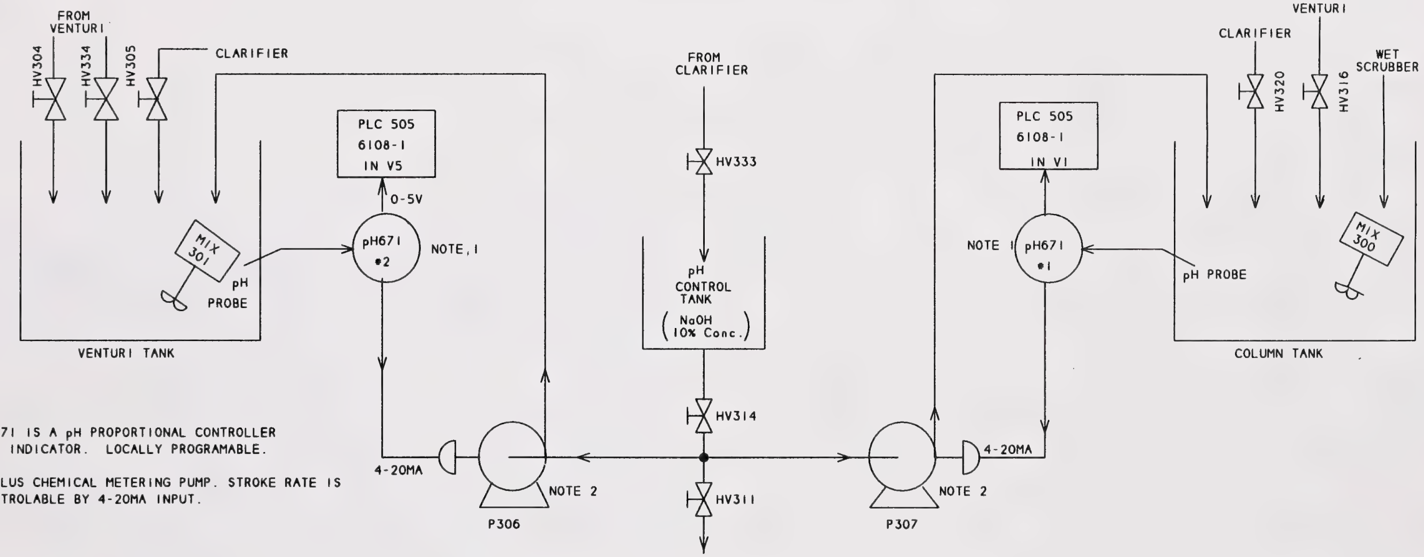


APPENDIX D: AIR/GAS RATIO CONTROL - CHAMBER #4



APPENDIX E: AIR CONTROL SELECT - CHAMBER #3/CHAMBER #4

IRB VENTURI TANK AND COLUMN TANK pH CONTROL.



NOTES: 1. pH671 IS A pH PROPORTIONAL CONTROLLER AND INDICATOR. LOCALLY PROGRAMABLE.

2. E-PLUS CHEMICAL METERING PUMP. STROKE RATE IS CONTROLABLE BY 4-20MA INPUT.

APPENDIX F: INCINERATOR VENTURI TANK pH CONTROL

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